MILLENNIUM SUPPLEMENT: PHYSICAL WORLD

VOL. 193, NO. 5 MAY 1998

# NATIONAL GEOGRAPHIC

PHYSICAL WORLD 2
CASCADIA 6
GRAY WOLVES 72
PRINCE EDWARD ISLAND 100
WHITBREAD RACE 118

## Unlocking the Climate Puzzle 38

OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY WASHINGTON, D.C.

Supplement to NATIONAL GEOGRAPHIC, May 1998

The darkest forest, the brightest desert, and measures of elevation—precise to one meter—are revealed in this computer-generated mosaic of Earth produced from satellite images.

THE MAIN MAP AND POLAR IMAGES WERE PREPARED FOR NATIONAL GEOGRAPHIC TELEVISION BY NASA'S JET PROPULSION LABORATORY FROM ADVANCED VERY HIGH RESOLUTION RADIOMETER WEATHER SATELLITE IMAGES AND OCEAN-DEPTH MEASUREMENTS COMPILED BY THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION.

Satellite images show polar ice (right and far left) at summer minimums, while lines trace the mean maximum reach of sea ice in winter.

Differences in solar heating drive winds, which in turn help drive ocean currents. Winds and currents distribute heat across the globe. Over the short term this creates weather; over the long term, climate.

# PHYSICAL EARTH

*Produced by National Geographic Maps for National Geographic Magazine*

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Washington, D.C. May 1998

SCALE 1:54,100,000 or 1 INCH = 854 MILES AT THE EQUATOR
Winkel Tripel Projection, Central Meridian 0°

MAP KEY
- Divergent boundary
- Convergent boundary
- Transform zone
- Notable earthquake of the 20th century
- 20th-century quake greater than 6.5 magnitude
- Notable volcanic eruption of the 20th century
- Known volcanic eruption during the past 10,000 years
- Hot spot
- Warm ocean current
- Cold ocean current
- Prevailing wind

AGE DATA FROM R. CLARK BURCHFIEL AND R. DIETMAR MUELLER

Like a living thing, Earth is in constant motion. More than four billion years of creeping and tumultuous change, driven by heat escaping from the planet's interior, has created continents and ocean basins. Chains of volcanoes mark the present-day boundaries of 16 rocky slabs, or plates, that make up the planet's crust. Plates move apart along diverging boundaries known as spreading centers as new crust emerges. Hot magma rises from Earth's interior and spills out onto the seafloor as basalt along 40,000 miles of mid-oceanic ridges, including the spreading center that bisects the Atlantic. Where plates come together along converging boundaries known as subduction zones, old, dense, cold crust sinks into ocean trenches, mixing with seawater and melting in the hot mantle below to fuel explosive volcanoes and violent earthquakes such as those around the Pacific's Ring of Fire.

Along transform faults plates haltingly slip past each other, their bursts of motion triggering earthquakes such as those that occur in the San Andreas region of California or at the fracture zones perpendicular to the Mid-Atlantic Ridge.

Magma rising at spreading centers pushes plates away from ocean ridges. Crust sinking at trenches pulls plates toward subduction zones. Under these forces, plates travel at rates of a half inch to six inches a year, carrying the continents with them. Buoyed by the low density of their granite roots, continents lie above the cycle of crust creation and destruction. Continental collisions along converging boundaries thrust up mountains such as the Himalaya and squeeze highlands such as the Tibetan Plateau to greater elevations. The force of such collisions radiates across thousands of miles, spawning earthquakes like those that shake Iran and China.

Where diverging boundaries begin to form within continents, rift valleys split the land, as in East Africa, and sometimes, as under the Red Sea, later widen to form infant ocean basins. Even far from plate boundaries, plumes of magma can rise through the crust and emerge as volcanoes. As plates move, these hot spots remain stationary, creating a series of extinct and active volcanoes such as the Emperor Seamount Chain and the Hawaiian Islands.

AERIAL VIEWS OF MOROCCO'S QUARKIZ MOUNTAINS BORDER THE RIDES OF THIS MAP. DATA FOR THE IMAGES WERE COLLECTED BY THE LANDSAT SATELLITE AND PROCESSED BY EARTH SATELLITE CORPORATION.

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MILLENNIUM IN MAPS

# PHYSICAL EARTH

NATIONAL GEOGRAPHIC SOCIETY

Supplement to NATIONAL GEOGRAPHIC, May 1998

*Design: David E. Chandler, Sally S. Summerall Research: Marguerite B. Hunsiker, Patricia Q. Strohm Edit: Gus Platis, Lisa R. Ritter. Production: Neal J. Edwards, Micki A. Laws, James E. McClelland, Jr., Nancy J. Schweickart, John T. Sebastian. Text: Karen E. Lange, author; Jeanette K. Howard, researcher; John S. Bailey, typography. Art by Pierre Mion. Graph by Julia Sifers. Relief by Tibor Tóth, adapted from original art by Ralph Scotese*

*Consultants: Nevin Bryant, Jet Propulsion Laboratory, NASA; B. Clark Burchfiel, Massachusetts Institute of Technology; Core Research Center, USGS; Brian T. Huber, Smithsonian Institution; National Ice Core Laboratory, USGS; Ocean Drilling Program, Joint Oceanographic Institutions; Christopher R. Scotese, PALEOMAP Project, University of Texas at Arlington; Raymond Siever, Harvard University; James Zachos, University of California, Santa Cruz*

Geologists entered the 20th century beset by mysteries: enigmatic patterns of earthquakes and volcanoes, continents shaped like puzzle pieces, and beds of the same fossils on opposite sides of oceans. By the mid-1960s enough evidence had been collected for most to accept a revolutionary answer for a multitude of questions—geology's grand theory of plate tectonics. Using this theory, earth scientists explain churning in Earth's inner layers, prehistoric climates, drifting continents, and spreading seas. As before, their work is grounded in the physical makeup of the planet. But new technologies allow them to drill ever deeper into ice caps and seafloors, gathering data about the distant past.

Evidence of life multiplied 570 million years ago with the appearance of animals such as trilobites, which survived as fossils because of durable exoskeletons.

ASAPHOCRYPHICALIS ROBUSTA, 500 MILLION YEARS OLD. PHOTOGRAPH BY JAMES L. AMOS

2000 NATIONAL GEOGRAPHIC

LANDSAT 7 SATELLITE WILL ORBIT AT AN ALTITUDE OF 438 MILES

400 MILES

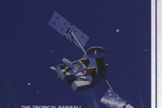
THE HUBBLE SPACE TELESCOPE CIRCLES EARTH 378 MILES UP

Atmospheric drag on spacecraft declines with increasing altitude. Despite high atmospheric temperatures, satellites stay cool because the extremely thin air does not conduct heat well.

300 MILES

THE SPACE SHUTTLE CROSSES ALL THE ATMOSPHERE'S LAYERS.

311 MILES



THE TROPICAL RAINFALL MEASURING MISSION ORBITS AT 217 MILES

200 MILES

From 55 to 190 miles, temperature rises from minus 135 F to 2300 F, while pressure continues to drop. High-energy solar particles create auroras near both Poles.

100 MILES

Rains hug Earth, leaving upper air dry, but at 50 miles trace water vapor can freeze around meteorite dust, forming clouds. Between 13 and 18 miles solar radiation turns oxygen to ozone, which shields Earth from ultraviolet radiation. Man-made chlorine compounds thin the ozone layer.

THE CONCORDE AND A WEATHER BALLOON FLY IN THE ATMOSPHERE'S LOWEST LAYERS.

EXOSPHERE

THERMOSPHERE

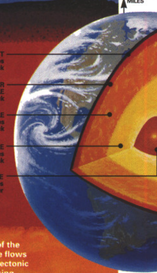
MESOSPHERE

STRATOSPHERE

50 MILES

28 MILES

6 MILES




Hotter rock of the upper mantle flows below rigid tectonic plates, releasing heat as it rises and falling as it cools.

## 94 MILLION YEARS AGO

## Drifting Apart

As soon as the last pieces collided to form the supercontinent of Pangaea, it began to break up, rifting into three parts: Eurasia-North America, Africa-South America, and Antarctica-Australia-India. Next, about 120 million years ago, each of those pieces divided, perhaps pushed apart by hot plumes rising from the mantle. The fragmentation isolated evolutionary lines such as marsupials and created a warm climate for dinosaurs. Newly formed mid-ocean ridges displaced seas, flooding continents with heat-absorbing water, while shallow seas between continents carried equatorial currents toward the Poles.

## 65 MILLION YEARS AGO

## End of a World

In the last years of the dinosaurs temperatures and sea level dropped. Across the central part of India, which was still drifting away from what had been Gondwana, volcanic eruptions released huge floods of lava as well as dust and aerosols that blanketed the planet, blocking solar radiation and mixing with water vapor to fall as acid rain. But the reason most scientists give for why half the world's plant and animal species, including all the dinosaurs, became extinct lies on the Yucatán Peninsula and in the Gulf of Mexico, where a trillion-ton asteroid or comet moving at 100,000 miles an hour left the 113-mile-wide Chicxulub crater. Far more powerful than any volcanic eruption, the explosive impact set off storms, tsunamis, and global forest fires. Dust and soot high in the atmosphere left Earth cold and in darkness.

## 237 MILLION YEARS AGO

## Coming Together

About 300 million years ago Gondwana and northern continents collided, creating Pangaea, a landmass that stretched from Pole to Pole. Within opened Tethys, ancestor of the Mediterranean. Around the supercontinent lay the Panthalassic Ocean, ancestor of the Pacific. The enlarged ocean basin caused sea level to fall, while the north-south land barrier blocked ocean currents that circulated oxygen. Scientists speculate that these events and a vast outpouring of lava in Siberia may have caused Earth's largest extinction, 250 million years ago. Surviving reptiles spread across Pangaea, evolving into diverse forms that gave rise to the dinosaurs.

## 390 MILLION YEARS AGO

## Continental Rises

Laurentia (North America) collided with Baltica (northern Europe) and later with Avalonia (Britain and New England), a fragment of Gondwana. The Caledonian mountains and northern Appalachians were thrust up along the boundary. As the continents squeezed together, ocean basins widened and sea level fell, uncovering more land and withdrawing saltwater barriers between rivers and lakes. Freshwater fish migrated freely, and plants colonized land. Later, as carbon-rich vegetation was buried, carbon dioxide levels in the atmosphere fell, allowing Earth to cool.

## 650 MILLION YEARS AGO

## The Great Divide

After the earliest known supercontinent, Rodinia, began to split apart 750 million years ago, spreading centers opened huge ocean basins, pushing one group of pieces north and the other south over the Pole. Mountains rose and glaciers grew on high peaks, even at the Equator, as the northern fragments collided with what is now Africa. By 600 million years ago all the fragments had reunited, forming another supercontinent, Pannotia.

## 514 MILLION YEARS AGO

## Balmy Seas

A chunk of Pannotia tore off and drifted north, leaving the continent of Gondwana at the South Pole. As the fragment approached equatorial latitudes, it splintered into three parts that were mostly submerged. Between lay warm, shallow seas where multicellular animals with exoskeletons first appeared 570 million years ago. The sudden abundance of fossil evidence after three billion years of primitive life is called the Cambrian explosion.

# Earth in Flux

Six hundred fifty million years ago, on a planet already four billion years old, a supercontinent was fragmenting into pieces that were half submerged under high seas. Over several hundred million years the pieces reassembled, then broke apart again, migrating thousands of miles to become the continents we know today. The magnitude of this transformation has become clear only in this century, with the theory of plate tectonics.

First attempts at reconstructing past worlds—based on the incomplete theory of continental drift—relied on geologic formations and the shapes of continents. "It is just as if we were to refit the torn pieces of a newspaper by matching their edges and then check whether the lines of print run smoothly across," wrote Alfred Wegener, who in 1915 used the coasts of Africa and South America to reconstruct the supercontinent Pangaea.

The reconstructions on this map, created by paleogeographer Christopher R. Scotese of the University of Texas at Arlington, synthesize recent work. Like Wegener, Scotese considers the evidence of ancient fossil beds and rocks that have been split along complementary coastlines by younger ocean basins. Unlike Wegener, Scotese uses radioactive isotopes to date formations and can plot their positions in relation to the Poles by measuring ancient magnetic fields. Current techniques reveal the latitude but not the longitude of past continents, so these reconstructions involve informed guesses. The most distant evidence stretches back to 1.1 billion years ago, when all land but northcentral Africa was gathered in a supercontinent called Rodinia, with what is now North America at its center.

## 50 MILLION YEARS AGO

## High and Dry

Pangaea's breakup ended and a new cycle of continental collision began. Africa hit Europe, and India rammed into Asia, thrusting up the Alps and Himalaya. Continental compression led to widened ocean basins, which lowered sea level. Migration routes emerged, and land animals flourished. But greater expanses of heat-reflecting land helped cool Earth and allowed ice to remain year-round in Antarctica.

## 18,000 YEARS AGO

## Deep Freeze

At the peak of the last great ice age, glaciers frosted northern Europe, northern North America, and Antarctica. Water locked in ice transformed familiar continental outlines, lowering sea level 300 to 500 feet and exposing continental shelves and a land bridge from Asia to the Americas. Within the next 8,000 years the glaciers receded, the oceans rose, and the climate turned warmer and wetter. Along its farthest margin the retreating ice left signs of its passage, such as the Great Lakes, pressed into the landscape.

## ENGINE OF CHANGE

Born as a ball of cosmic debris, Earth melted from the heat of meteorite impacts and radioactivity, then cooled into layers, heavier rock sinking toward the center, lighter rising to the surface. Most scientists believe that gases expelled in the process created an early atmosphere, while water released from molten rocks formed the oceans.

Some 4.5 billion years later the planet's solid iron-and-nickel inner core remains almost as hot as the sun's surface, and escaping heat continues to stir Earth's interior and rupture its skin. Studies of the manner in which seismic waves pass through the planet provide evidence that cooling crust, subducting where plates come together, sinks all the way to the border between the mantle and the liquid iron-and-nickel outer core, where it lies as slabs of old ocean basin. The same studies detect magma plumes rising from the bottom of the mantle to feed volcanoes. Deeper still, within the outer core, which begins about 1,800 miles below the surface, convective currents driven by heat rushing upward power a dynamo that gives Earth its magnetic field and, recent theories suggest, spin the moon-size inner core slightly faster than the planet rotates.



65 MILLION YEARS AGO
**Dinosaurs Became Extinct and Early Primates Emerged**
THE AMMONITES, INCLUDING *MAORITES DENSICOSTATUS*, WENT EXTINCT WITH THE DINOSAURS. PHOTOGRAPH BY COMSTOCK, TOWNSEND P. DICKINSON

55 MILLION YEARS AGO
**Temperature Peak**
Subtropical forests extended into the Arctic during a period of global greenhouse warming. Ancestors of crocodiles inhabited northern Europe, Asia, and North America.

10 MILLION YEARS AGO
**Red Sea Opened**

3.5 MILLION YEARS AGO
**Land Linked North and South America**
Thrust up like a bridge between the Americas, the isthmus of Panama diverted a current that flowed from the Caribbean to the Pacific. Forced north, it carried moisture that fed Arctic snows. In the cooler, drier global climate, African forests turned to grasslands roamed by human ancestors called australopithecines.

*AUSTRALOPITHECUS AMANENSIS* SKULL; ART BY ROB WOOD

230,000 YEARS AGO
**Neandertal**
To survive along the edges of glaciers lying year-round over much of Europe and Asia, this now vanished line of hominids, having evolved a short, stocky build that retained body heat, wore animal skins and built fires.

18,000 YEARS AGO
**Maximum Reach of the Last Glaciation**
At their peak during the last glacial advance, ice caps grew to three times their present volume. During the next 8,000 years they retreated, part of a long-term cycle of freezing and thawing that appears linked to changes in Earth's orbit.


## HOTHOUSE TO ICEHOUSE

Roller-coaster dips and jumps in global temperature and ice volume chart climate during the past 65 million years, when Earth experienced a series of ice ages. Temperatures peaked 55 million years ago, followed by cooling between 50 and 35 million years ago that allowed ice to cover Antarctica. Earth warmed briefly, then grew steadily colder from 14 million years ago onward, with ice returning to Antarctica and glaciers later spreading across the northern reaches of North America and Europe. Plate tectonics may have launched the global cooling: The rise of steep mountains led to erosion, which could have lowered levels of heat-trapping carbon dioxide by burying plant and animal remains and setting off chemical reactions that eventually bound the gas in ocean bottoms. Drifting continents also cut off warm ocean currents and created cold ones. Geologist James Zachos, who compiled the data for this chart from analyses of microscopic shells within sea cores, contends that at critical times even small changes can push the climate system over a threshold, producing radical results.

*This logarithmic scale compresses the earliest time periods (at left) and expands more recent epochs.*

## SHAFTS INTO THE PAST

Millennium after millennium Earth's features are covered by debris—snow on ice caps, mud on continents, tiny seashells on ocean floors, and flows of lava everywhere. Since the 1960s scientists have drilled cores into these layers to read evidence of changes in climate and sea level, evolution and extinctions of living things, the turbulent birth and death of tectonic plates, and the age of continents. Ice cores have been recovered from 1.7 miles deep and 250,000 years into the past, providing samples of prehistoric atmospheres, seasonal snowfall, rocks crushed by glaciers, and dust from volcanoes and winds. Sea cores have reached 1.3 miles deep and 167 million years back in time, retrieving cross sections of old crust swept into abyssal trenches, pieces of the basalt that forms ocean basins, and marine sediments with microscopic shells whose chemistry, like that of polar ice, reflects temperature fluctuations. Beyond 200 million years ago—the age of the oldest surviving oceanic crust—scientists must turn to the eroded centers of continents, the most ancient of which is almost four billion years old. Beyond that, the record stops.

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## TIME LINE

The cores below give scientists a view deep into the past, filling gaps in the record from surface rocks and fossils.

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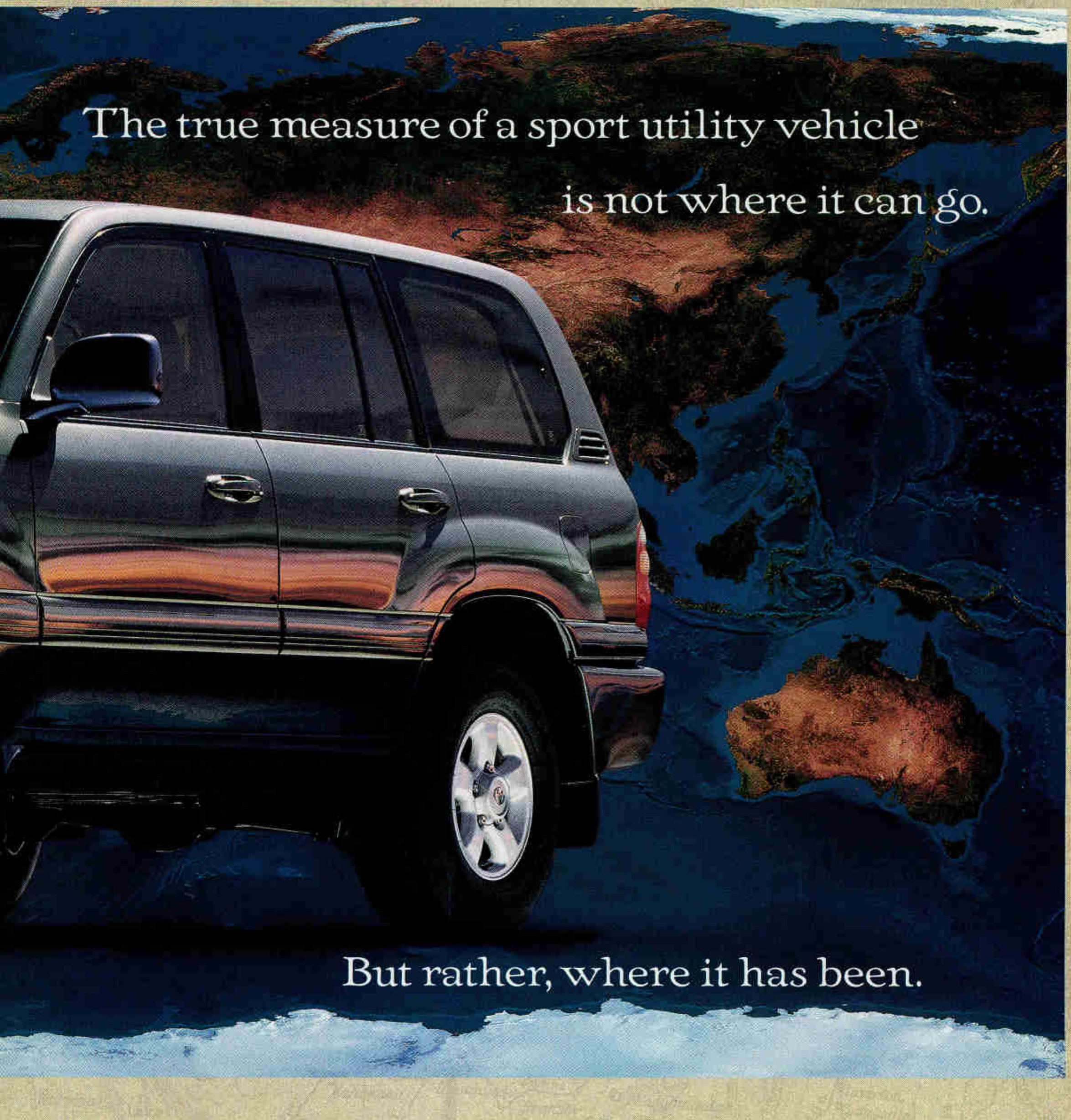


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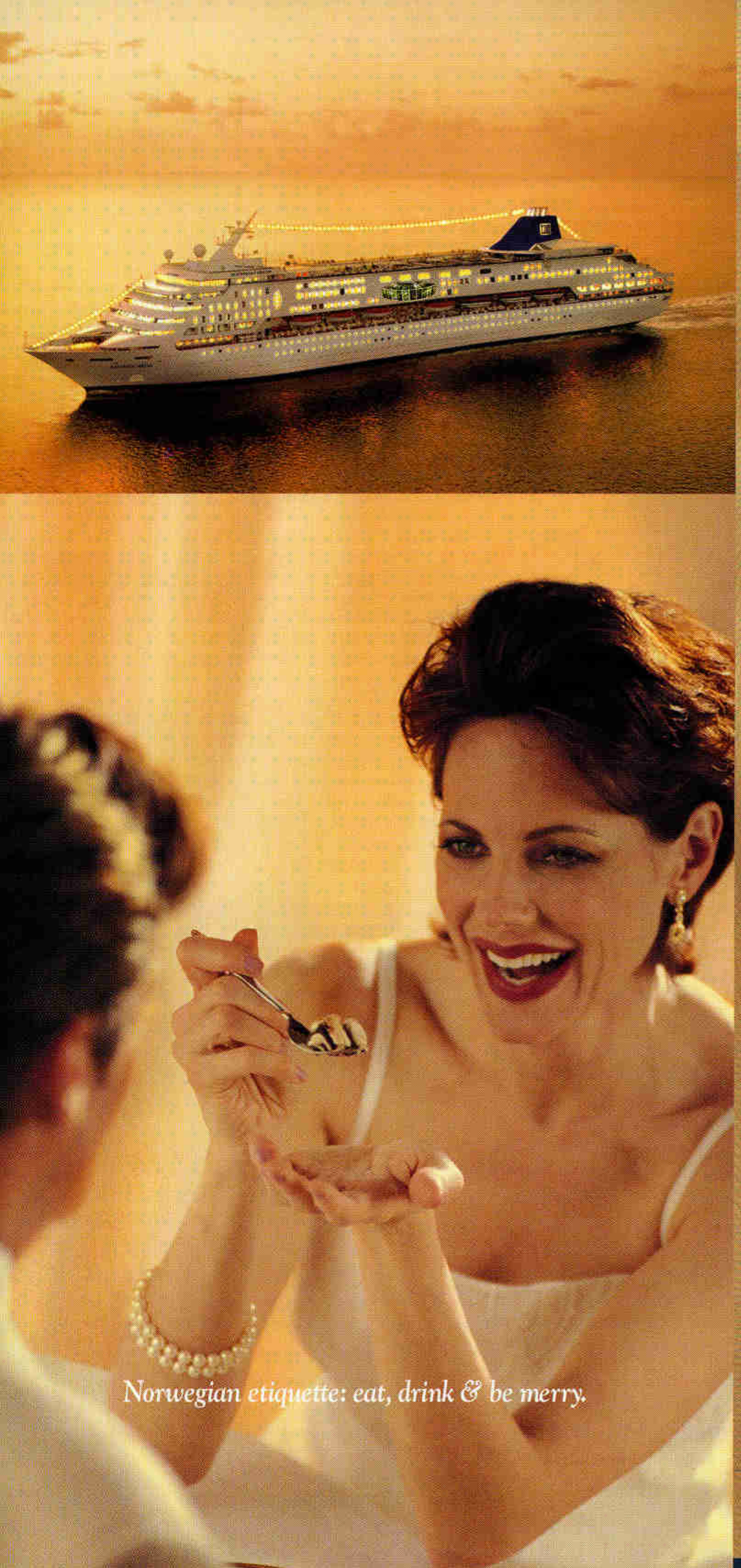


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# NATIONAL GEOGRAPHIC

MAY 1998


The Millennium Series/Physical World







2 **Physical World: How Will the Planet Change?**
*In our continuing coverage of the issues facing us as the millennium nears, we examine an Earth in constant motion.*
BY JOEL L. SWERDLOW
■ *Millennium Supplement: Physical World*

6 **Cascadia** *An earthquake and tsunami of cataclysmic scale struck the Pacific Northwest in A.D. 1700. The subterranean forces at work that day will rage again, unsettling news for a burgeoning region.*
BY RICK GORE PHOTOGRAPHS BY JIM RICHARDSON

38 **Unlocking the Climate Puzzle** *Earth warms and cools in natural cycles over the eons, scientists say, but we may be altering the rhythm with our dependence on fossil fuels.*
BY CURT SUPLEE PHOTOGRAPHS BY JOANNA B. PINNEO

72 **Return of the Gray Wolf** *Three years into a controversial project to reestablish the predator in the lower 48 states,* Canis lupus *is well on its way to recovery. Not everyone is cheering.*
BY DOUGLAS H. CHADWICK PHOTOGRAPHS BY JOEL SARTORE

100 **Prince Edward Island** *A pastoral realm of patchwork farms and sweeping Atlantic vistas, Canada's smallest province braces for the changes brought by a new eight-mile bridge to the mainland.*
BY IAN DARRAGH PHOTOGRAPHS BY SUSIE POST

118 **The Whitbread—Race Into Danger** *Violent seas of the southern Indian Ocean make for a wild ride for nine sloops sailing one of the roughest legs of an eight-month round-the-world race.*
BY ANGUS PHILLIPS PHOTOGRAPHS BY RICK TOMLINSON


## Departments


Behind the Scenes
Millennium Moments
Forum
Geographica
From the Editor

Flashback
On Television
Earth Almanac
Interactive
On Assignment
Geoguide


## The Cover

*In the shade of their tent members of a Tuareg family doze through midday heat near Timbuktu in drought-stricken Mali. Photograph by Joanna B. Pinneo*


Cover printed on recycled-content paper.

# people in progress

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NATIONAL GEOGRAPHIC

# *Behind the* Scenes

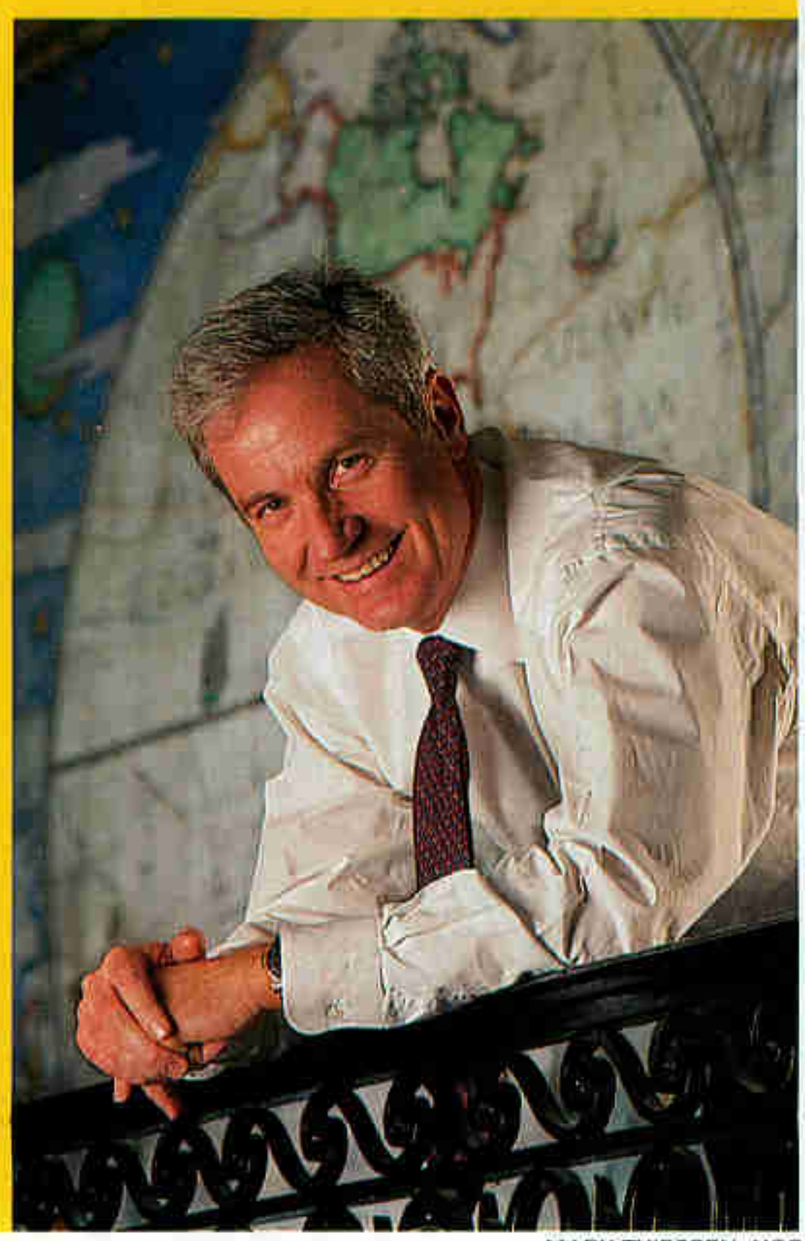

## Tracking Their Track Coach

Soon after the November 1997 GEOGRAPHIC arrived in their homes, two former students of Carol Johnston—the 85-year-old pole-vaulter featured in the story on aging (above)—contacted our Research Correspondence Division to reach their old coach. Everett Anderson and Pat Graham fondly recall Johnston's mentoring at Huntington Park High School in California. Johnston (above right, at left) also worked with 1939 track team members Harvey Graham, Tom DeVaughn, and Tex Winter—now a Chicago Bulls basketball coach. Pat Graham (right, at 17), now 75, laughingly said that his coach would probably remember him. "I'm the guy who dropped the baton in the relay during the league championship meet in 1940. I remember it like it was yesterday."

COURTESY CAROL JOHNSTON (TOP RIGHT); RICHARD C. BARRY

## Meet Our New President

"Following Alexander Graham Bell and three generations of Grosvenors is slightly intimidating—and a great honor," says John M. Fahey, Jr., 46, who succeeded Reg Murphy as President of the National Geographic Society on March 1. Fahey's career includes 19 years with Time Warner. Sailing is a favorite hobby: "I just bought a Hobie Cat. I hope I find time to use it."



MARK THIESSEN, NGS

*Aerodynamically speaking, a Dodge Stratus is one slippery car. Is it possible to see the future, then, in the rear-view mirror?*

*Dodge pioneered the cab-forward design concept – moving the wheels out to the corners and sliding the passenger compartment forward. Can cab-forward roominess create more room even in the trunk?*

*You'd expect a race car to be graded on a curve. Well, if race cars inspired us to modify a double-wishbone suspension, can you handle it?*

*Powder-coat paint technology will give you a paint finish tough enough to help protect a car's shiny overcoat from flying gravel. When it comes to what you'll expect down the road, do we have things pretty well covered?*

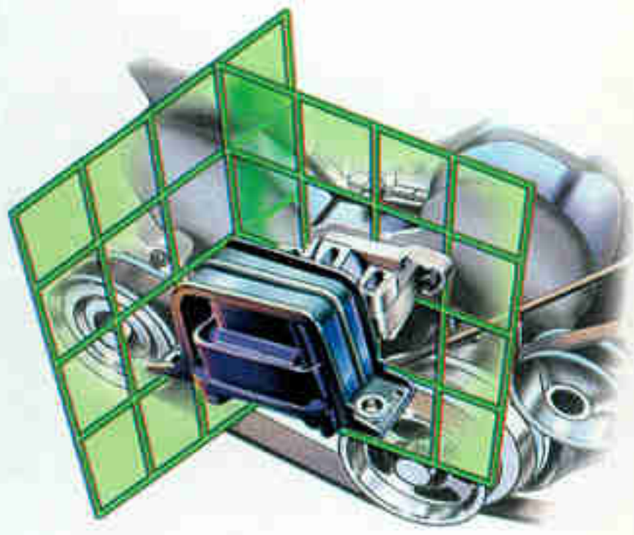
*It's a simple engineering principle: lose weight, gain performance. But can a whole battery of ideas that enhance performance include simply moving the battery?*

# These are the questions.

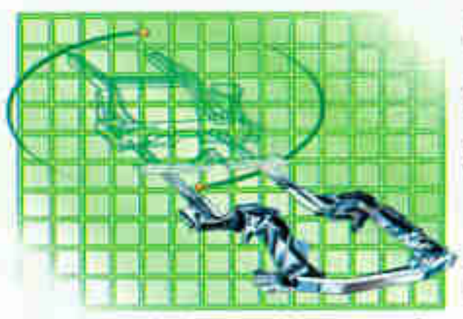
*Do you have to choose between the convenience of an automatic transmission and the performance of manual shifting? Or can an available AutoStick® transaxle shift an automatic a little more toward fun?*

*Let's see, there's more room up front. There's more room in back. Is everyone comfortable with cab-forward?*

*Take something as simple as an engine mount – a combination of steel and rubber that holds the engine to the frame rail. Can we mount a good argument that a device filled with liquid could minimize engine vibration and help make things quieter?*

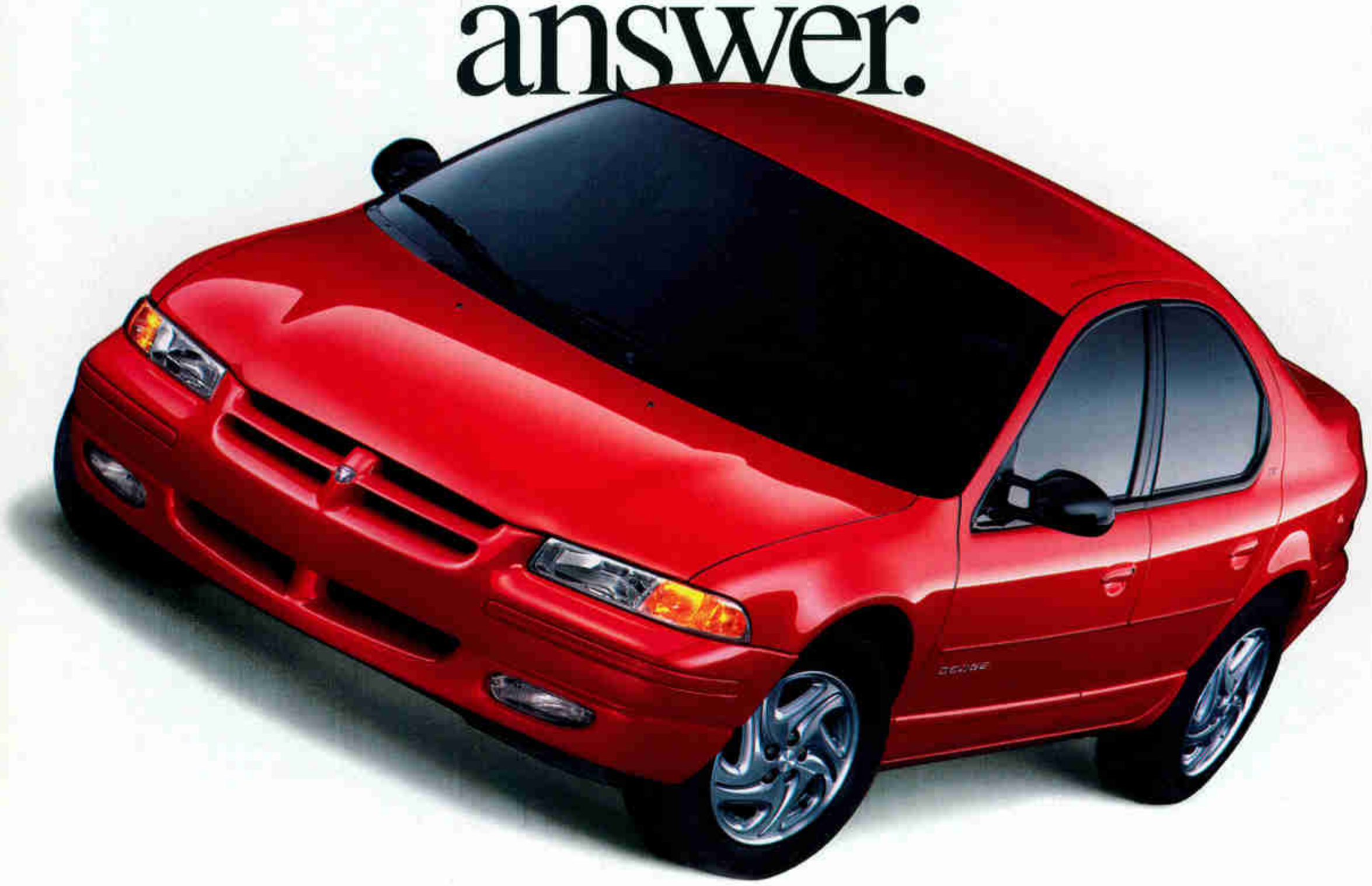


*Car chassis have traditionally been built on a "floor pan" design. Can a platform that incorporates a continuous rigid, ladder-type frame improve ride and handling characteristics? Can this help us reach a high level of performance?*



*Always use seat belts. Remember a backseat is the safest place for children.*

# This is the answer.



Stratus The New Dodge

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## Institute Transforms Classroom Landscapes

"It changed my life!" exclaims first-grade teacher Donna La-Roche (below) of Belmont, Massachusetts, about the Society's Geography Education Program.

PAULA LERNER (BOTH)

In 1989, when she attended the fourth annual Summer Geography Institute at our Washington, D.C., headquarters, she recalls, "I felt so inspired by the other educators and by the world-renowned experts who taught us. Everyone was so passionate about geography."

In fact her lesson plan on the geology of Earth's crust, illustrated by layers of colored dough cut with dental floss, was voted best elementary school presentation.

These days Donna conducts state and national workshops for other educators and has written numerous teacher guides. In her own class at Winn Brook School she doesn't offer geography as just one subject. "We learn it all day long."

Her students (above) present their torn-paper collage of a mountain yak habitat. Later the kids worked on map skills while doing "Geography Jumping Jacks"—shouting "Longitude" with arms up and "Latitude" with arms out.

"To teach," Donna says, "you take your opportunity wherever you find it."

Since its beginning, the Society's Geography Education Program has trained more than 12,000 teachers at the state and national levels.

ISAMU OSADA

## A Bear Artifact

A bear's den is rarely seen, but photographer Jim Brandenburg found one recently in northern Minnesota. Atop the dirt pile dug out by the bear sat a stone tool "that may have been used on a bear hide thousands of years ago," Jim says. Government archaeologists plan to search the site for signs of human habitation. "Where an object is can be as important as what it is," advises our staff archaeologist, George Stuart, "so when people find things, they should leave them and call experts."

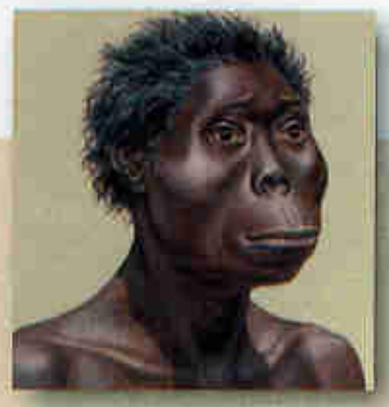
to sleep perchance to dream
perchance to mess with reality

fantasy is just another word
for fearless there will always be
a place in the world for rebels
the key to creativity is yanking
convention inside out

do
you
dream
in
sony?



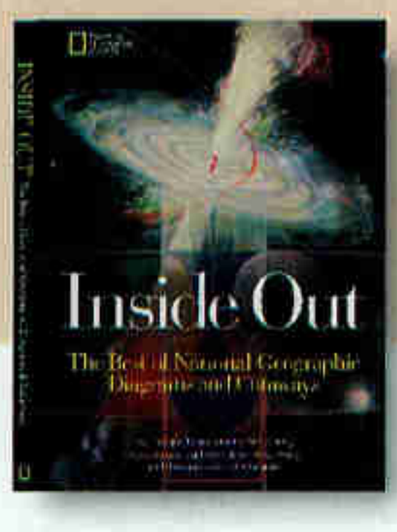
SONY

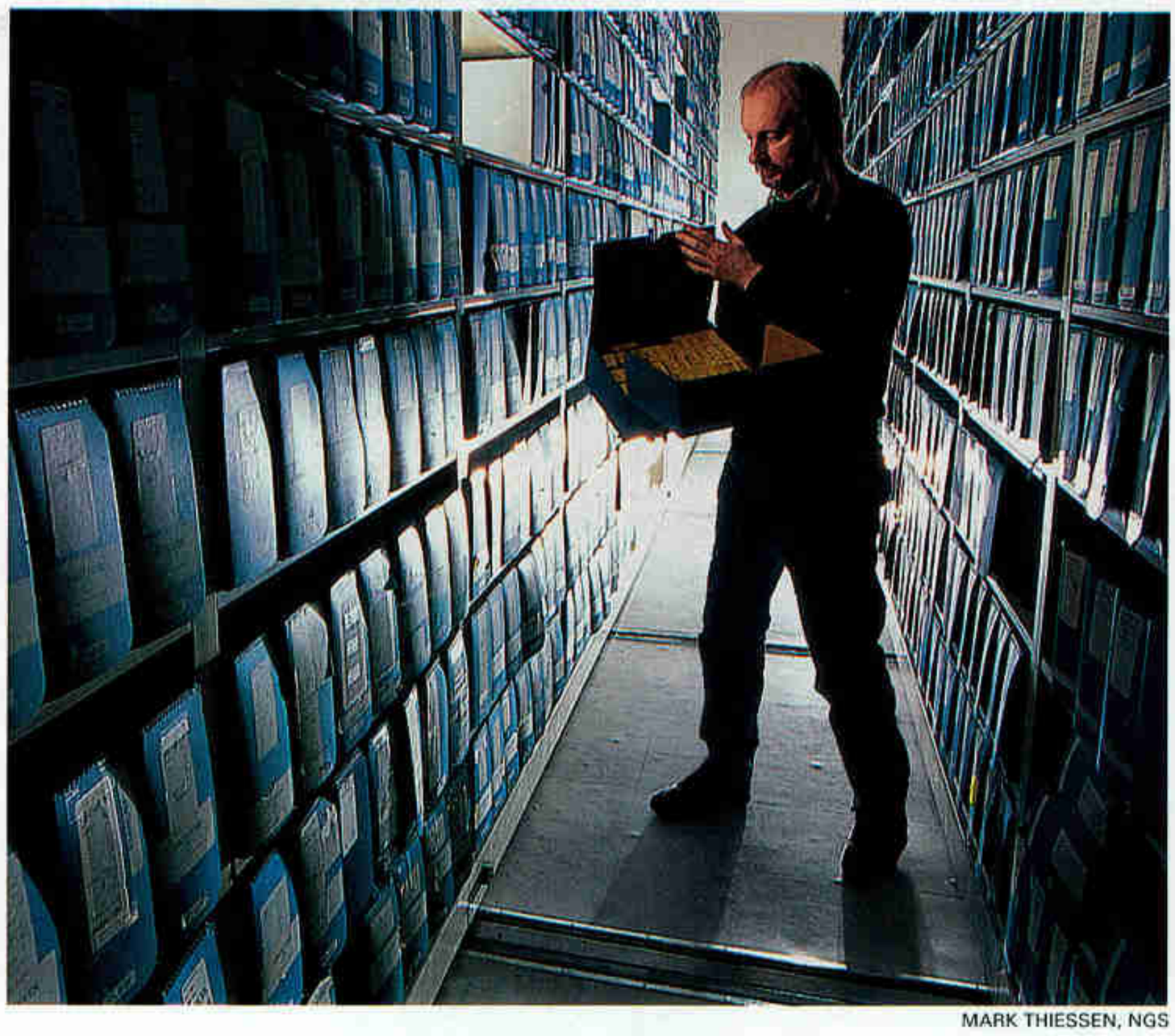


ART BY JAY MATTERNES

## Exploring Art

See beneath the surface with our new book *Inside Out*, featuring 60 of the best diagrams from the GEOGRAPHIC and Society books. You'll venture into St. Peter's Basilica, through Chornobyl, and around a two-million-year-old fossil, skull 1470 from Kenya (above). Artist Jay Matternes spent days there studying museum specimens to create this layered portrait.



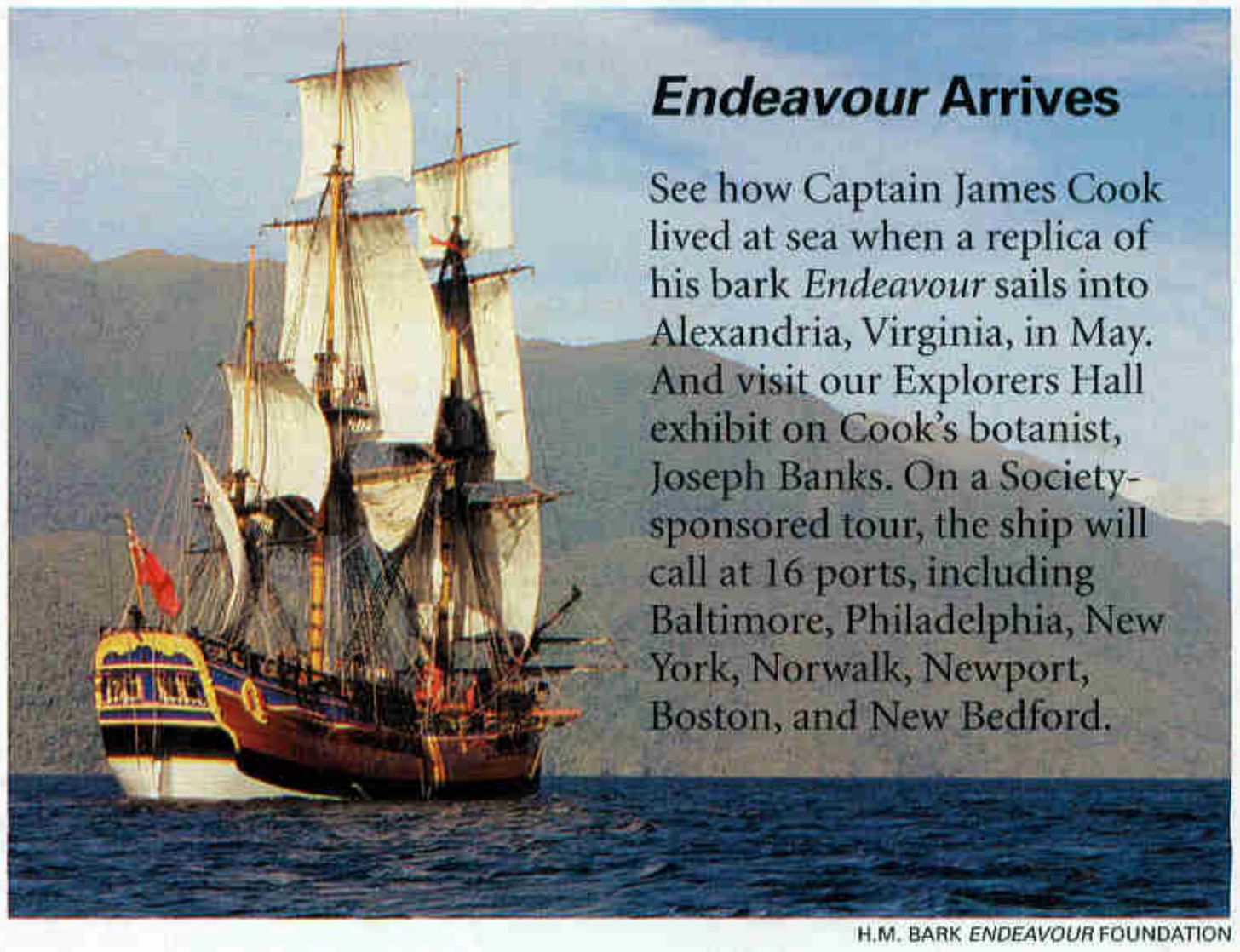



MARK THIESSEN, NGS

## He Gets the Picture

If someone needs an old photograph at National Geographic, Bill Bonner of the Image Collection is the man to see; he presides over more than eight million images in a climate-controlled basement lair at headquarters. He has at his fingertips such treasures as a set of Edward Curtis Native American portraits and our collection of 15,000 glass autochrome plates. But what Bill loves most are the old unpublished black-and-white pictures, which now find their way into our Flashback column. Trained as a trombonist, Bill picked up archival skills on the job during his 15 years working with old photos. He doesn't regret giving up a musical career. "If you like pictures," he says, "this is the place to work."

TEXT BY MAGGIE ZACKOWITZ



## *Endeavour* Arrives

See how Captain James Cook lived at sea when a replica of his bark *Endeavour* sails into Alexandria, Virginia, in May. And visit our Explorers Hall exhibit on Cook's botanist, Joseph Banks. On a Society-sponsored tour, the ship will call at 16 ports, including Baltimore, Philadelphia, New York, Norwalk, Newport, Boston, and New Bedford.

H.M. BARK *ENDEAVOUR* FOUNDATION

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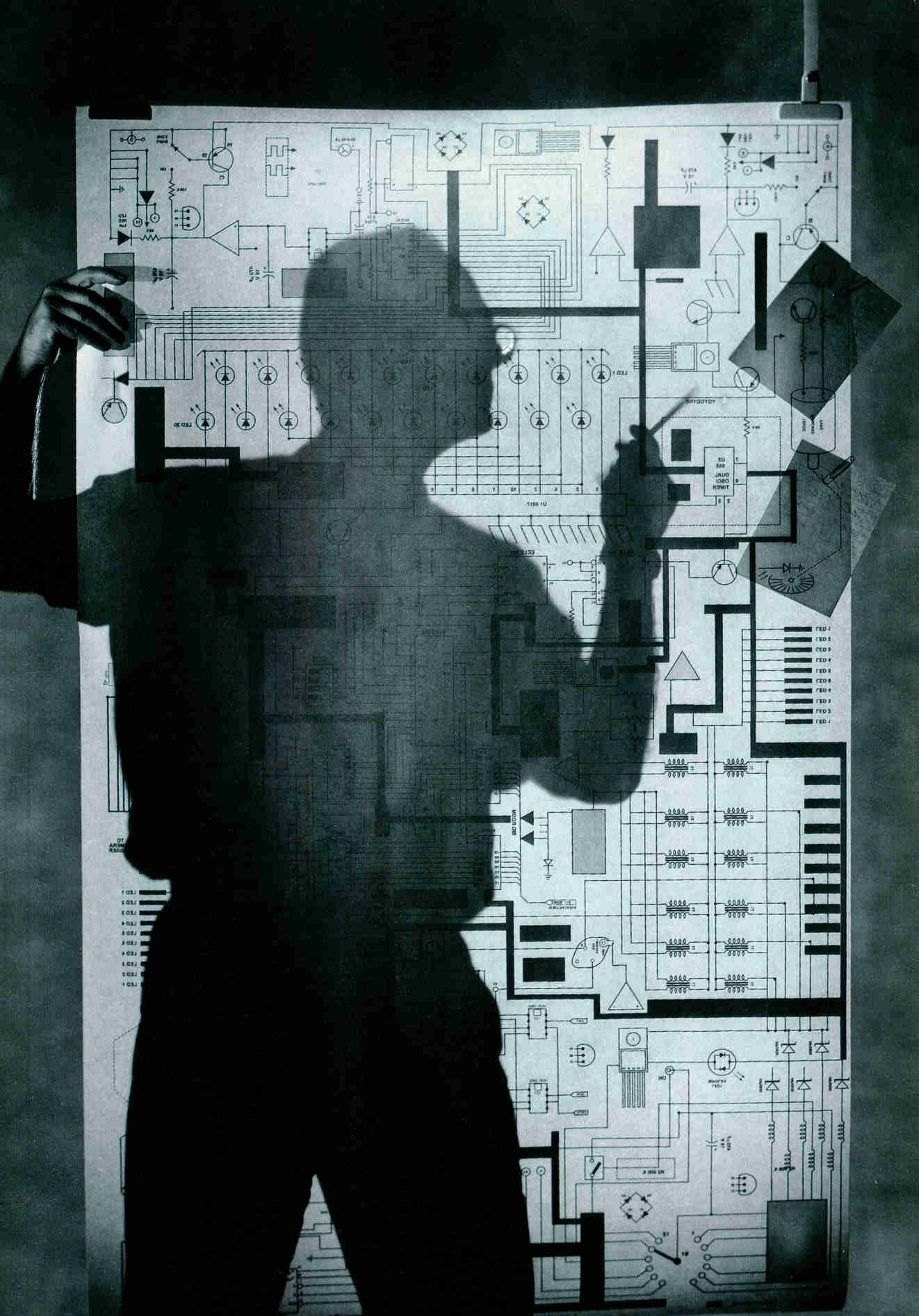

1997 Chevy Blazer turning stability claim based on USAC-certified dry lateral acceleration test. 1997 Ford Explorer braking comparison based on USAC-certified dry testing of 60-0 braking. Grand Cherokee fuel economy comparison based on 1997 EPA estimates of city/highway 21/27 Subaru and 16/21 Jeep Grand Cherokee. The ABC's of Safety: Air bags. Buckle up. Children in back.


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NATIONAL GEOGRAPHIC'S

# Millennium Moments

## From the Society's Start, an Eye on Nature

"This storm is by no means as violent as others which have occurred in the eastern part of the United States," wrote Brig. Gen. A. W. Greely in the first issue of National Geographic. "It is noted, however, as being one in which an unusual amount of snow fell"—some 40 inches or more in New England and New York.

The journal of the National Geographic Society devoted part of its October 1888 debut to the great blizzard of '88, signaling that we would monitor natural phenomena. Earthquakes and volcanic eruptions, typhoons and tornadoes have leaped to life in our pages. But as knowledge of the worlds above our heads and beneath our feet has grown, we have focused on the long-term. These Millennium Moments are culled from 110 years of attention to the physical world and all that's in it.

FROM MORRIS J. ELSING (ABOVE AND TOP)

**A CARIBBEAN DISASTER**
The mountain called Pelée loomed peacefully above the city of St.-Pierre on the island of Martinique at the turn of the century (above). But in May 1902 the volcano rained ash and death, destroying St.-Pierre (left) and its entire population—30,000 people. "At my feet lay the dead city, silent and gray," wrote Israel C. Russell, a geologist sent by the Society, in our July 1902 issue. "Not a green thing was in sight." Outside St.-Pierre, investigator Robert T. Hill noted, "There is not a visible sign remaining of one of the homes of the . . . people who inhabited them. Annihilation is the only descriptive term." Pelée has been mostly quiet for the remainder of the 20th century. But recent and continuing eruptions on the nearby island of Montserrat serve as vivid reminders that the forces of nature continue to be as powerful—and destructive—as ever.

OSAKA MAINICHI SHIMBUN

**TERROR STRIKES JAPAN**
An exploring party pulls away as Japan's Sakurajima, now called Ontake, belches ash and lava during the third day of January 1914 eruptions. Knowledge gained after the 1902 Pelée disaster helped limit the death toll from an accompanying earthquake to 35, despite the fact that 15,000 people lived in the "death zone," as we noted in April 1924.

**BAD FRIDAY IN ALASKA**
Anchorage's 4th Avenue lies in shambles after the March 27, 1964, Good Friday earthquake shook southern Alaska. With the force of 63,000 Hiroshima explosions, the quake caused havoc along a 500-mile rupture zone that stretched from Valdez to beyond Kodiak Island. It killed 131 people, left 4,500 homeless, and caused huge waves even in the Gulf of Mexico.

WINFIELD PARKS

**ROCKY MOUNTAIN WIDE**
An eight-foot-long panorama of the Canadian Rockies by Smithsonian Secretary Charles Walcott (detail, below) was folded into the June 1911 issue. Editor Gilbert H. Grosvenor said, "I was attempting to do something that no other editor had done."

CHARLES D. WALCOTT

### Physical World Milestones

■ **Precambrian Time (4.6 billion-540 million years ago)**
Planet Earth takes shape as solar gases and dust combine under the force of gravity. Radioactivity and energy released by random meteorites heat this rocky mass. Dense iron and nickel sink to form a core; lighter rocks establish the continental crust. Volatile gases, expelled as the crust solidifies, form Earth's atmosphere. Rain eventually fills the oceans.

Single-celled organisms, the planet's first life, appear.

Around 1.1 billion years ago the earliest supercontinent, Rodinia, forms, linking almost all of Earth's surface.

Some 350 million years later Rodinia splits apart, leaving ocean basins between landmasses.

The first complex lifeforms—including the first animals—appear in the ancient seas.

■ **Paleozoic Era (540-245 m.y.a.)**
Beginning about 540 million years ago, multicellular animals with skeletons proliferate, an event known as the Cambrian explosion. Trilobites (three-lobed shelled creatures) and mollusklike brachiopods dominate the world's oceans.

Early vegetation colonizes land.

Forests grow in swampy areas. Amphibians and insects appear.

The planet's landmasses collide and combine to create a new supercontinent, Pangaea.

Low sea level and an outpouring of lava from Siberian volcanoes 250 m.y.a. contribute to the greatest extinction ever. Surviving reptiles evolve into dinosaurs that later rule the world.

The Tethys Sea, forerunner of the modern Mediterranean, opens.

■ **Mesozoic Era (245-65 m.y.a.)**
Beginning 180 million years ago Pangaea breaks up, forming two major landmasses, Gondwana in the south and Laurasia in the north. Later splits separate North America from Europe, Africa from South America, Antarctica and Australia from India.




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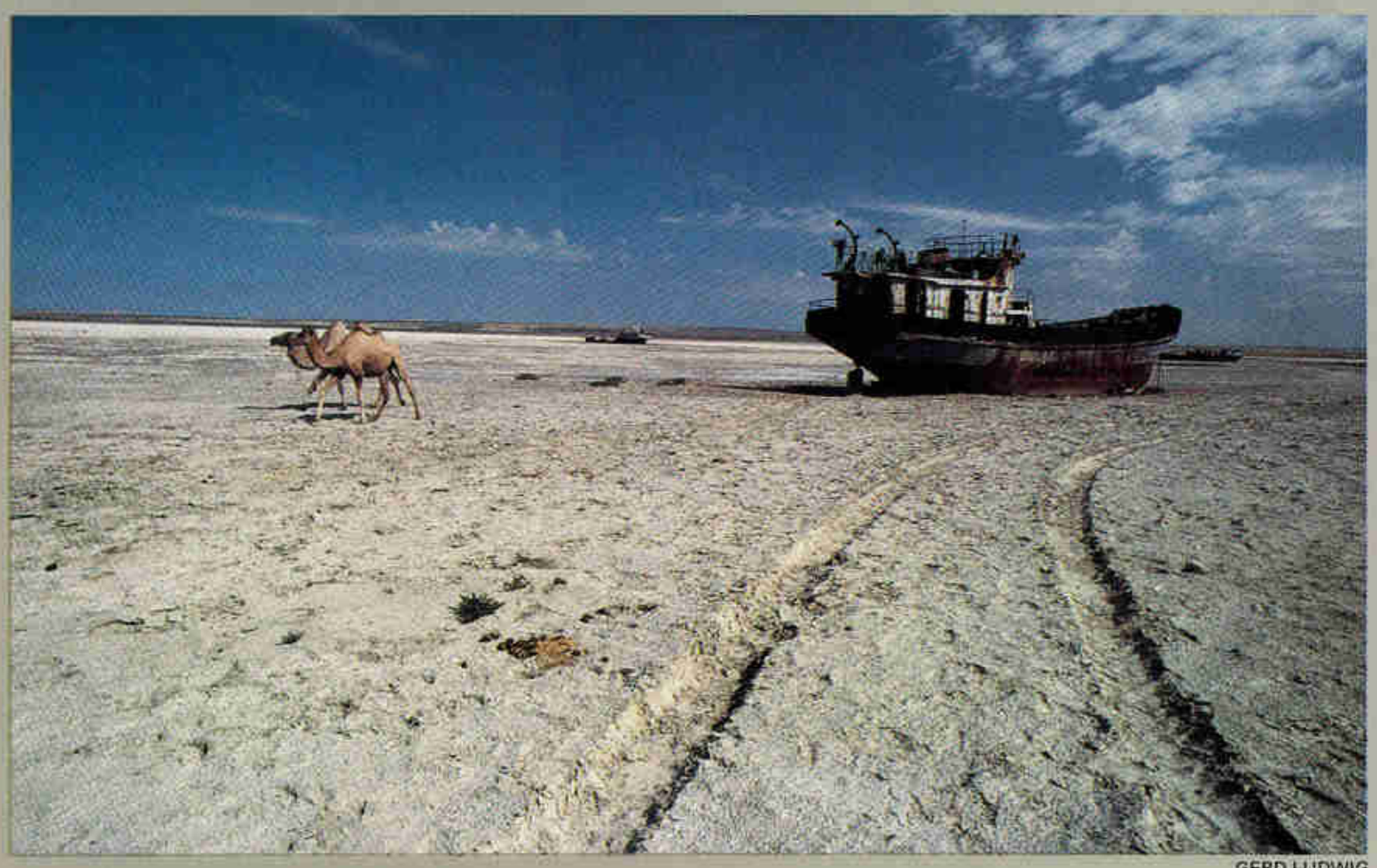
JASPER D. SAYRE

JOHN EDMOND, MIT AND NATIONAL SCIENCE FOUNDATION

**DOWN IN THE SMOKY VALLEY**
Photographer in a hot spot documents a fumarole in Alaska's Valley of Ten Thousand Smokes for an April 1919 article. A Society team discovered the region after a volcanic eruption; five NGS expeditions and resulting articles helped influence President Woodrow Wilson to create Katmai National Monument.

**LIFE AT THE BOTTOM**
Rich in minerals, water pours out of hydrothermal vents on the Pacific Ocean floor, seen in the December 1981 issue. The vents, "black smokers," eject hydrogen sulfide, which is gobbled up by bacteria that in turn feed giant tube worms and hordes of crabs, clams, mussels, and other creatures.

**A MAN-MADE DESERT**
Camels plod where boats once sailed on the Aral Sea, now less than half its former size. Soviet planners diverted water from feeder rivers to irrigate fields. They "killed rivers, even a sea; killed forests and tundra; and killed people," Assistant Editor Mike Edwards wrote in the August 1994 issue.



GERD LUDWIG

Flowering plants appear.

A major period of uplift and deformation sees the rise of the Rocky Mountains of North America between 100 and 65 million years ago.

A meteorite crashes into the Yucatán region, and the resulting dust darkens the skies. Another extinction wipes out much of the world's fauna and flora, including the dinosaurs. Tiny mammals survive and evolve into forms that will soon dominate the globe.

■ **Cenozoic Era**
**(65 m.y.a. to present)**
Widespread volcanism in the North Atlantic and the Caribbean creates global warming that brings about major changes in mammal life. The first true primates—lemurs—and the earliest hoofed animals debut on the planetary stage.

Earth's temperature peaks 55 million years ago, then cools for 27 million years. Ice sheets blanket East Antarctica. Another brief warming ends some 14 million years ago when glaciers spread southward across Europe and North America, including Greenland.

The African plate strikes the plate carrying Europe, thrusting up the Alps.

The Himalaya begin to rise after India collides with Asia 50 million years ago. A period of rapid uplift occurs 20 million years later. At 25 million years ago the Tethys Sea closes and shrinks to form the Mediterranean.

Primates that evolve into modern apes make their debut in the Oligocene epoch, which begins 36 million years ago. So do primitive horses and monkeys. Later bears and dogs appear, along with flowering plants and trees much like today's.

The Red Sea opens ten million years ago.

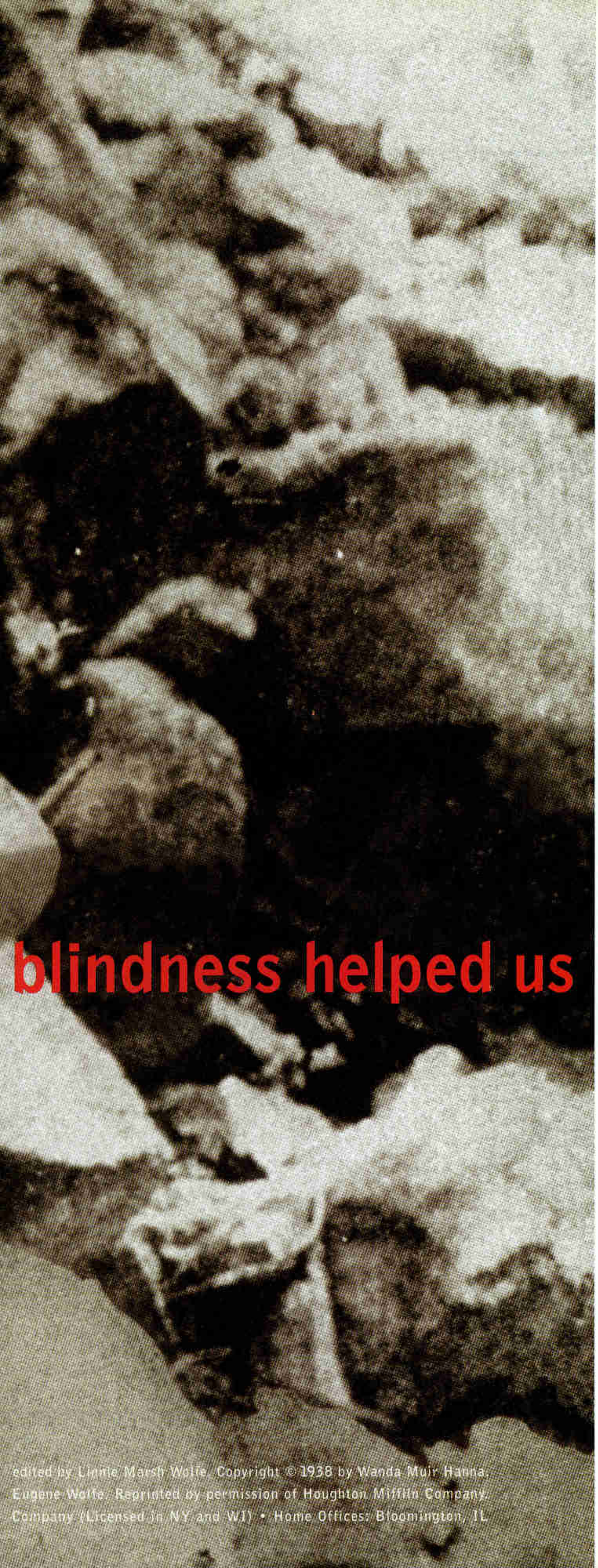
Uplift 3.5 million years ago creates the Isthmus of Panama, linking North and South America.

The first known bipedal hominids, australopithecines, stride across Africa's Great Rift Valley four million years ago.

Mammoths and other large mammals flourish throughout temperate zones.

First members of the genus *Homo,* which includes modern humans,


Photo from JOHN OF THE MOUNTAINS
Renewed © 1966 by John Muir Hanna and Ralph




A Scottish-born machinist blinded in an industrial accident, he swore if he ever regained his sight he would devote himself to the inventions of Nature. And regain it he did. In the 1880s, he became the country's first environmentalist and fought tirelessly to preserve the matchless beauty of places like Yellowstone and Yosemite Valley. With his passion and commitment, John Muir helped establish the world's first national parks, and gave us a vision of the beauty that surrounds us all.

## all to see.

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create and use stone tools. *Homo erectus* spreads out of Africa into Europe and Asia. Glaciers blanketing the Northern Hemisphere recede, providing more territory for human expansion. By 12,000 years ago North and South America are populated. At the same time, megafauna, such as mammoths and giant sloths, begin to disappear in the Americas.

Farming begins in the Fertile Crescent along the Tigris and Euphrates Rivers.

Mount Mazama in the Pacific Northwest erupts in 5700 B.C., forming Crater Lake.

Sumerians develop the first writing system, recording on clay tablets physical events that affected their civilization.

Thera volcano erupts in the Aegean Sea about 1630 B.C., contributing to the demise of Minoan civilization on the island of Crete.

An eruption of Vesuvius in A.D. 79 buries the Roman cities of Pompeii and Herculaneum.

Little ice age chills the world from A.D. 1450 to 1850, raising fears of approaching glaciers. But warmer temperatures ease the concerns.

Sicily's Mount Etna roars to life in 1669, killing about 20,000 people.

Three earthquakes centered at New Madrid, Missouri, shake the U.S. in 1811-12 and alter the course of the Mississippi River.

In an 1815 eruption that kills 92,000 people, Indonesia's Tambora releases six million times more energy than an atomic bomb and darkens skies everywhere.

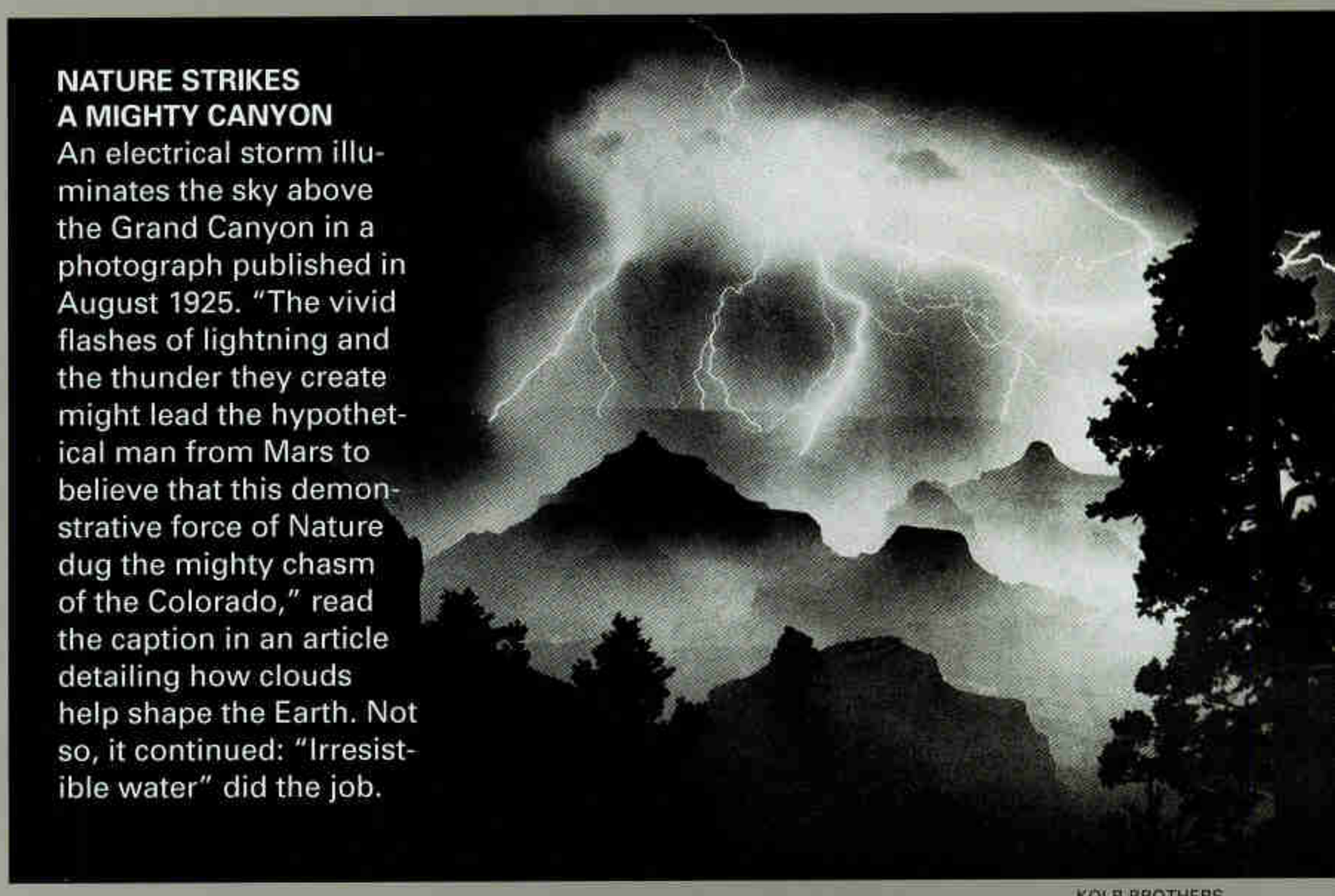
Indonesia's Krakatau volcano produces an 1883 explosion heard 3,000 miles away. A resulting tsunami drowns 36,000 people.

In 1906 a 7.7 magnitude quake and resulting fire destroy most of San Francisco, California.

Centered in southern Chile, a 1960 earthquake with a magnitude of 9.5 is the highest on record.

An underwater volcanic eruption off Iceland in 1963 produces new land, Surtsey, the first time scientists have been able to document the birth of an island.

Washington State's Mount St. Helens unleashes a devastating eruption in 1980, which is still yielding valuable scientific data.

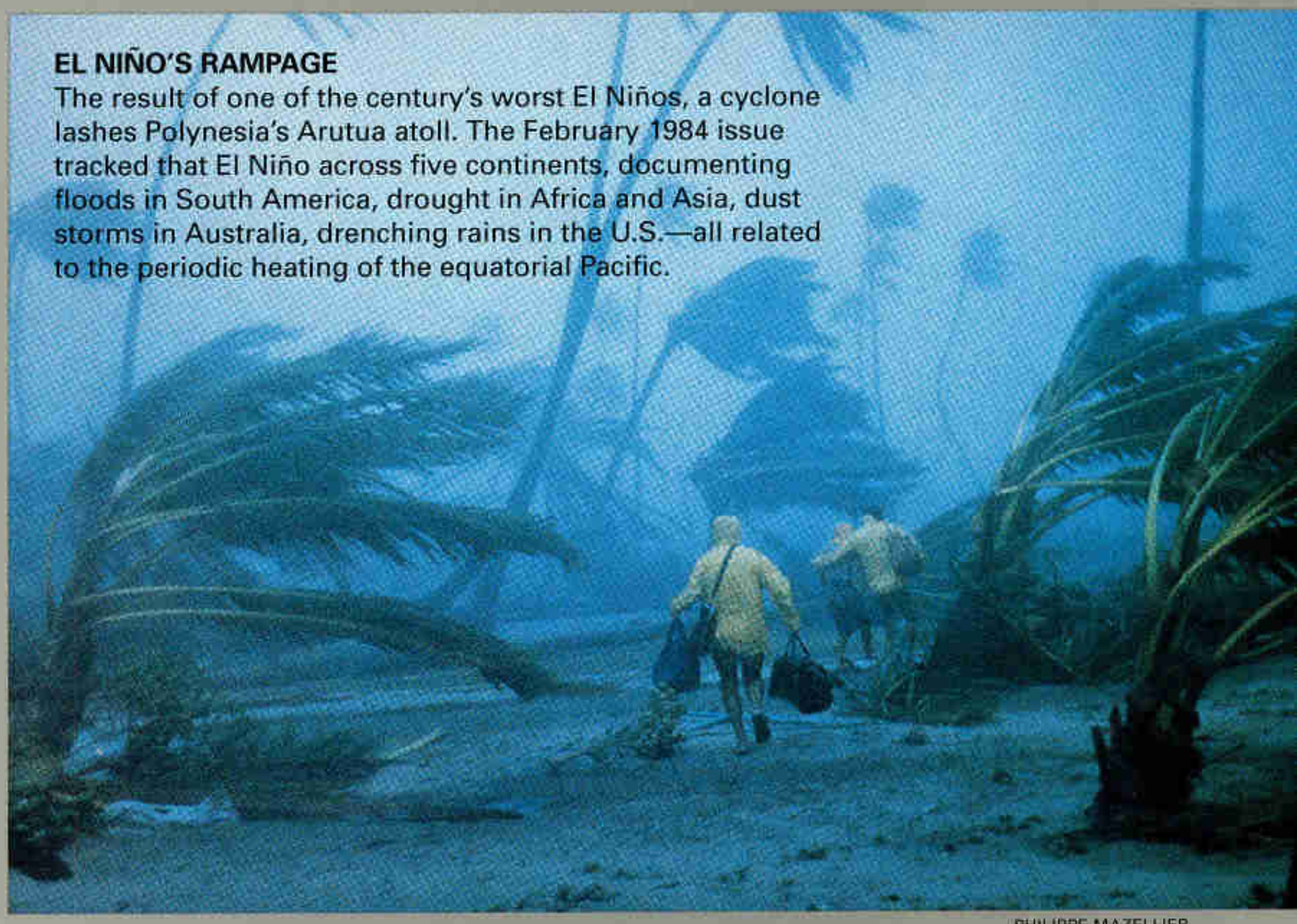


**NATURE STRIKES A MIGHTY CANYON**
An electrical storm illuminates the sky above the Grand Canyon in a photograph published in August 1925. "The vivid flashes of lightning and the thunder they create might lead the hypothetical man from Mars to believe that this demonstrative force of Nature dug the mighty chasm of the Colorado," read the caption in an article detailing how clouds help shape the Earth. Not so, it continued: "Irresistible water" did the job.

KOLB BROTHERS

**SPOUTING OFF TOGETHER**
Six waterspouts form simultaneously over the Sulu Sea off the Philippines in a photograph published in December 1943. A tornado over water, a spout is a funnel-shaped column of moist wind that develops downward from a line of cumulus clouds. A spout can pack winds up to 200 miles an hour and race along at 10 to 15 miles an hour, though it usually lasts for just a few minutes.

ALEKO E. LILIUS



**EL NIÑO'S RAMPAGE**
The result of one of the century's worst El Niños, a cyclone lashes Polynesia's Arutua atoll. The February 1984 issue tracked that El Niño across five continents, documenting floods in South America, drought in Africa and Asia, dust storms in Australia, drenching rains in the U.S.—all related to the periodic heating of the equatorial Pacific.

PHILIPPE MAZELLIER



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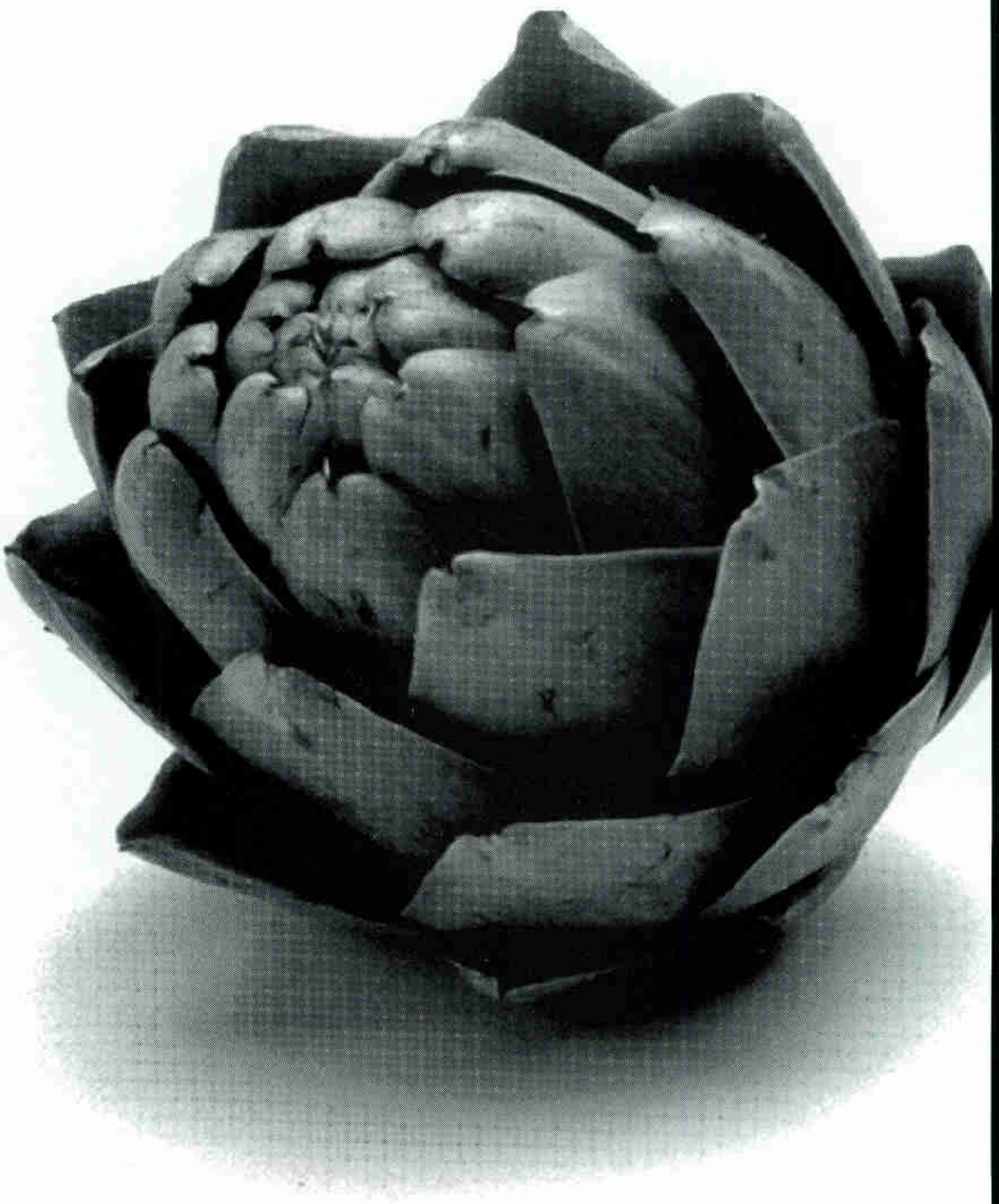

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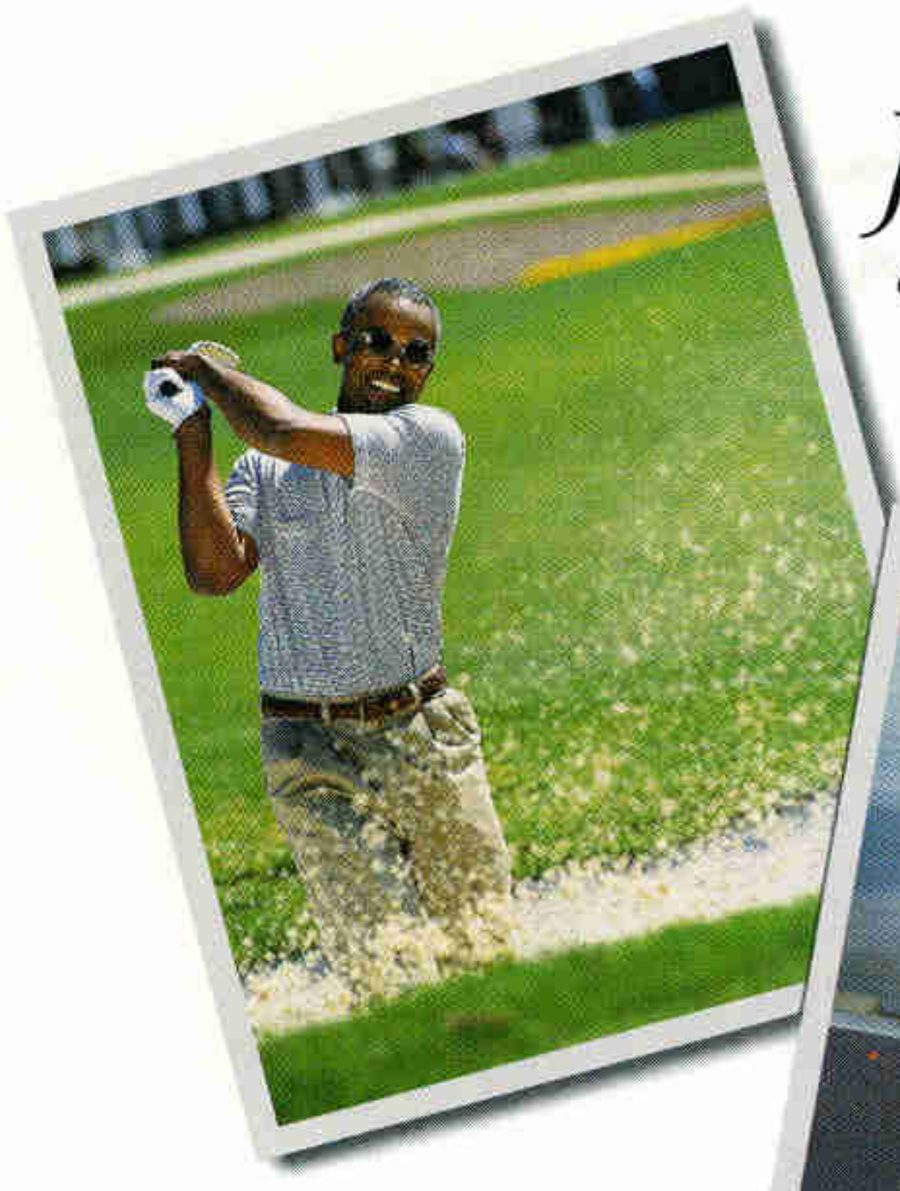
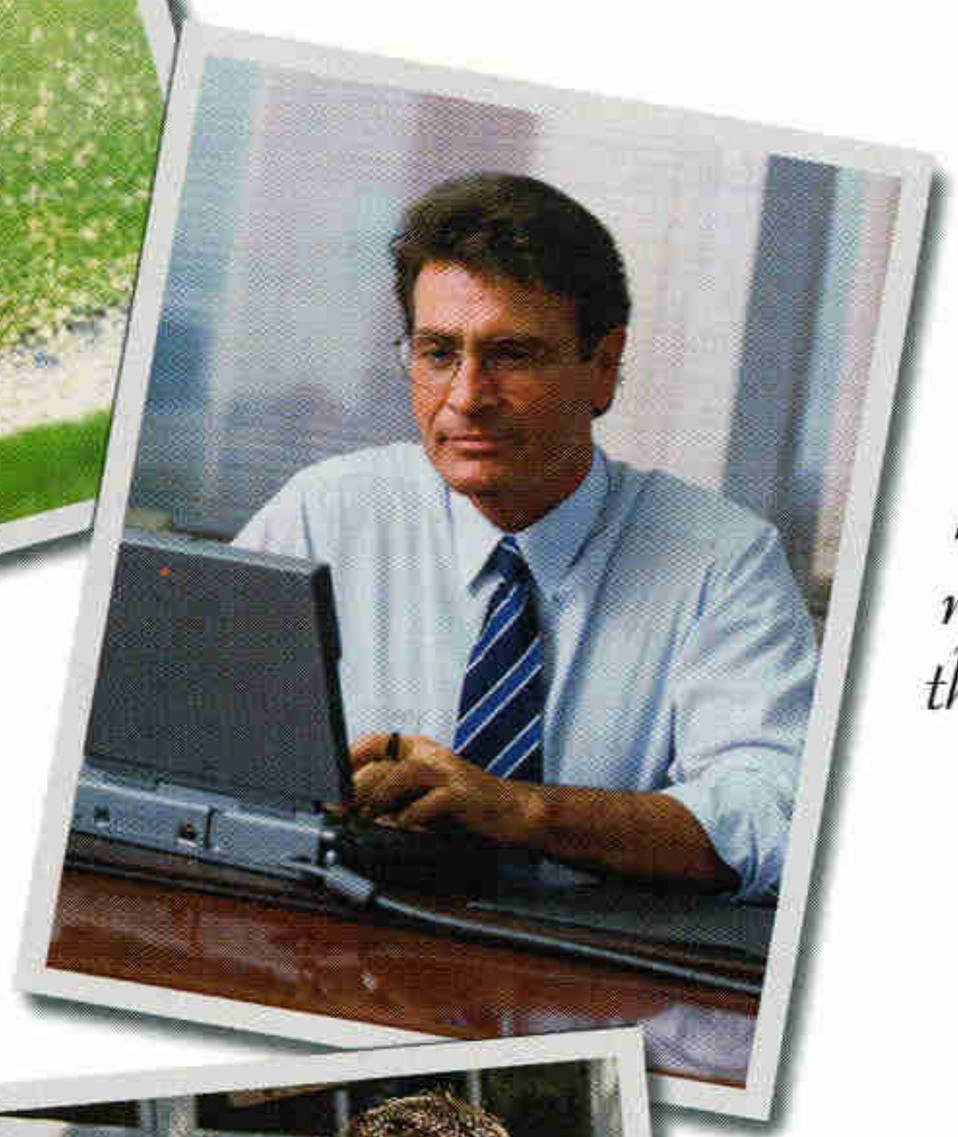


*Jeff Wood, father of three and weekend pro, made the change last year.*



*George Evans, successful stockbroker, made the analysis, then made the change.*

*Richard and Tina Runyan made the change, before they made the big move.*

*Mrs. Debbie Minnis, juggler of house, kids and career made the change, to make life easier.*

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# Forum

*A number of readers responding to our January 1998 issue chastised us for joining in the world celebration of the arrival of the next millennium in the year 2000 rather than 2001. Others congratulated us for articles on Amelia Earhart and polar bears.*

## Making Sense of the Millennium

To suggest that there is debate about when the new millennium begins is to suggest that 999 might equal 1,000. A millennium is one thousand years, and it is not over until the end of that thousand years. The next millennium begins with the 1,001st year. While it is convenient to celebrate the goose eggs on the odometer, and I will be out celebrating with the rest of them, the unalterable fact remains that the new millennium begins on January 1, 2001.

BRYAN TAYLOR
*Raleigh, North Carolina*

If you want to say that the next cultural age (whatever that means) begins in the year 2000, as the sixties might be said to have started in 1960 instead of 1961, fine. But explain it honestly. Technically the decade of the sixties did not start until the first day of 1961; the new millennium will not start until the first day of 2001. Of course it's a technicality, but in science technicalities matter.

FORREST E. FRIBERG
*Circle Pines, Minnesota*

*Indeed the year 2001 marks the start of the third millennium. But just as most people have trouble thinking of 1960 as the last year of the '50s, so they have ignored the fact that 2000 is the last year of the 1900s and are anticipating celebrating that date. We too look forward to the turn of the calendric odometer—in the spirit of the following letter.*

Your editorial says that the GEOGRAPHIC might be jumping the gun on the millennium. *Au contraire.* I believe it will take each of us that long to contemplate the opportunities for personal and societal change that it presents, if we choose to make it an opportunity rather than just another passing.

PATRICIA FINDLEY
*Lees Summit, Missouri*

You left out a subject, religion, that also plays a vital role in the destiny of humans throughout the world.

T. CHRIS SILLIMAN
*Sacramento, California*

The articles were both perplexing and thought provoking. The foldout photograph of the hot pool in Yellowstone was so intriguing. I've never been out there, and it made me realize how little I know about the world. But with all the material you send to me, I'm starting to understand more.

ASHLEY RICHARDSON
*Tallahassee, Florida*

## Amelia Earhart

I have been researching women pilots for over ten years, and I was sorry to see Elinor Smith quoted, impugning Amelia's flying skills, in the otherwise excellent piece by Virginia Morell. Smith has been slinging mud at Earhart and her husband, George Putnam, for years, and I lay it down to jealousy. Amelia got her pilot's license in 1923 (not 1929 as Smith once wrote) and in 1929 was the third American woman to win a commercial license.

SUSAN BUTLER
*Pine Plains, New York*

In July 1943 when I was copilot of a PV-1 stationed in Hawaii, I was ordered to reconnoiter Baker Island, where an airstrip was to be constructed. We arrived in the vicinity of Baker about the same time in the morning that Amelia would have arrived at Howland Island, which is 50 miles north and about the same size, both being flat islands about a mile in diameter. Our six planes flew search patterns for over an hour with no results, because fleecy clouds cast shadows on the ocean that looked just like islands. I can understand Amelia's problem if she ran into the same cloud formations.

WILLIAM E. ANDERSON, JR.
*Pioneer, California*

As a professional pilot, I can assure you that no pilot with a normal sense of self-preservation would stubbornly continue searching for an obscure open-ocean target until the fuel ran out. A prudent pilot would conserve enough fuel to reach an alternate destination, in Earhart's case the British-held Gilbert Islands. But due to navigational errors she and Noonan apparently flew into the Japanese-held Marshalls. Researchers over the years have interviewed many longtime residents of the Marshalls who said Japanese soldiers captured a Caucasian man and woman. If not Earhart and Noonan, who?

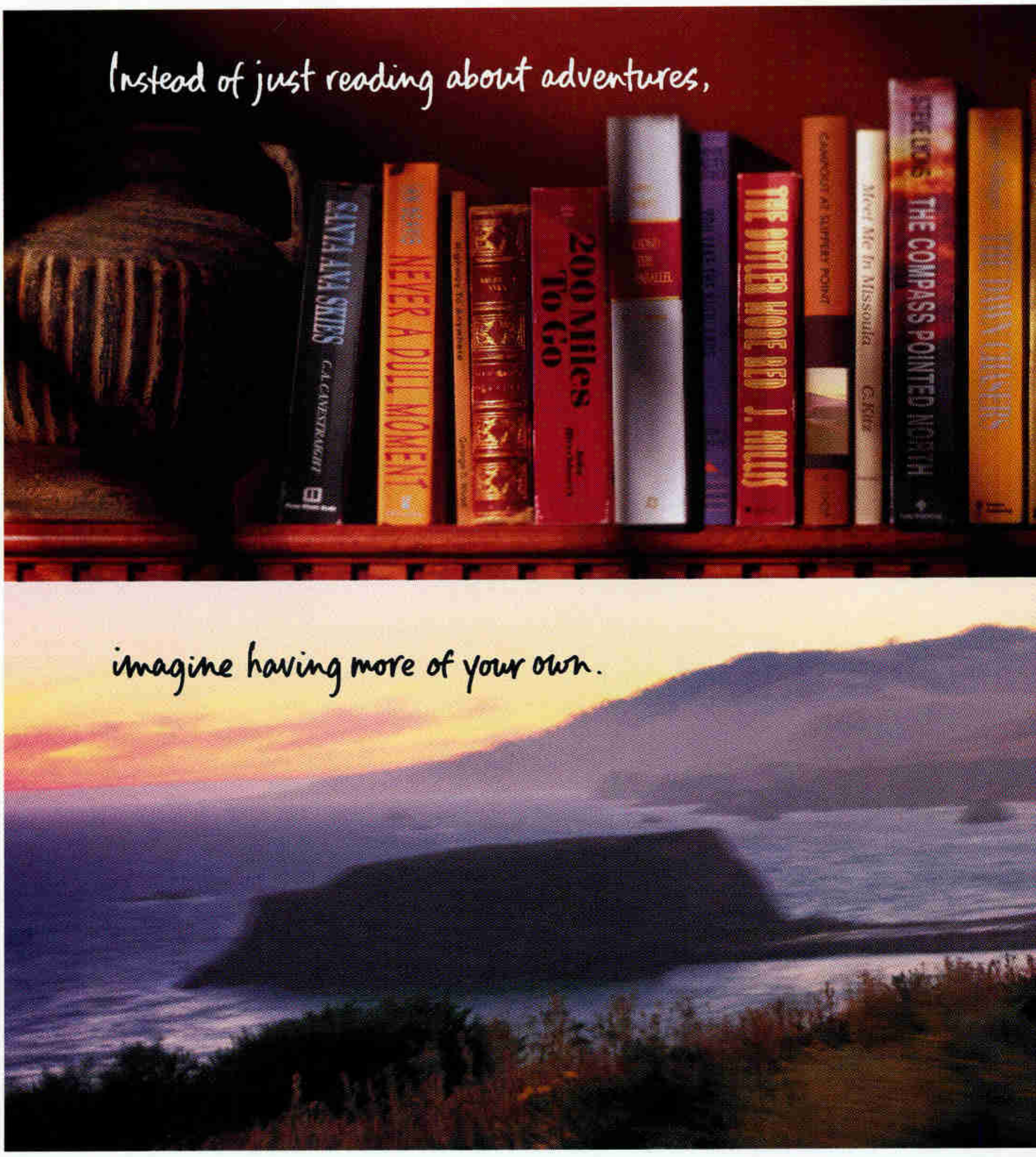
GERRY BRUDER
*Kenmore, Washington*

In recognition of Earhart's achievements, Zonta International memorializes her through the Amelia Earhart Fellowship Award. The program supports women pursuing graduate degrees in aerospace sciences and engineering. Since 1938 Zonta has invested more than four million dollars to award 808 fellowships to women from 51 countries. Earhart continues to inspire young women everywhere.

JEAN KIEFFER
*Mason, Ohio*

## Blackpool, England

As a native of Blackpool, I thoroughly enjoyed your article. I left there when I was 14. The number of

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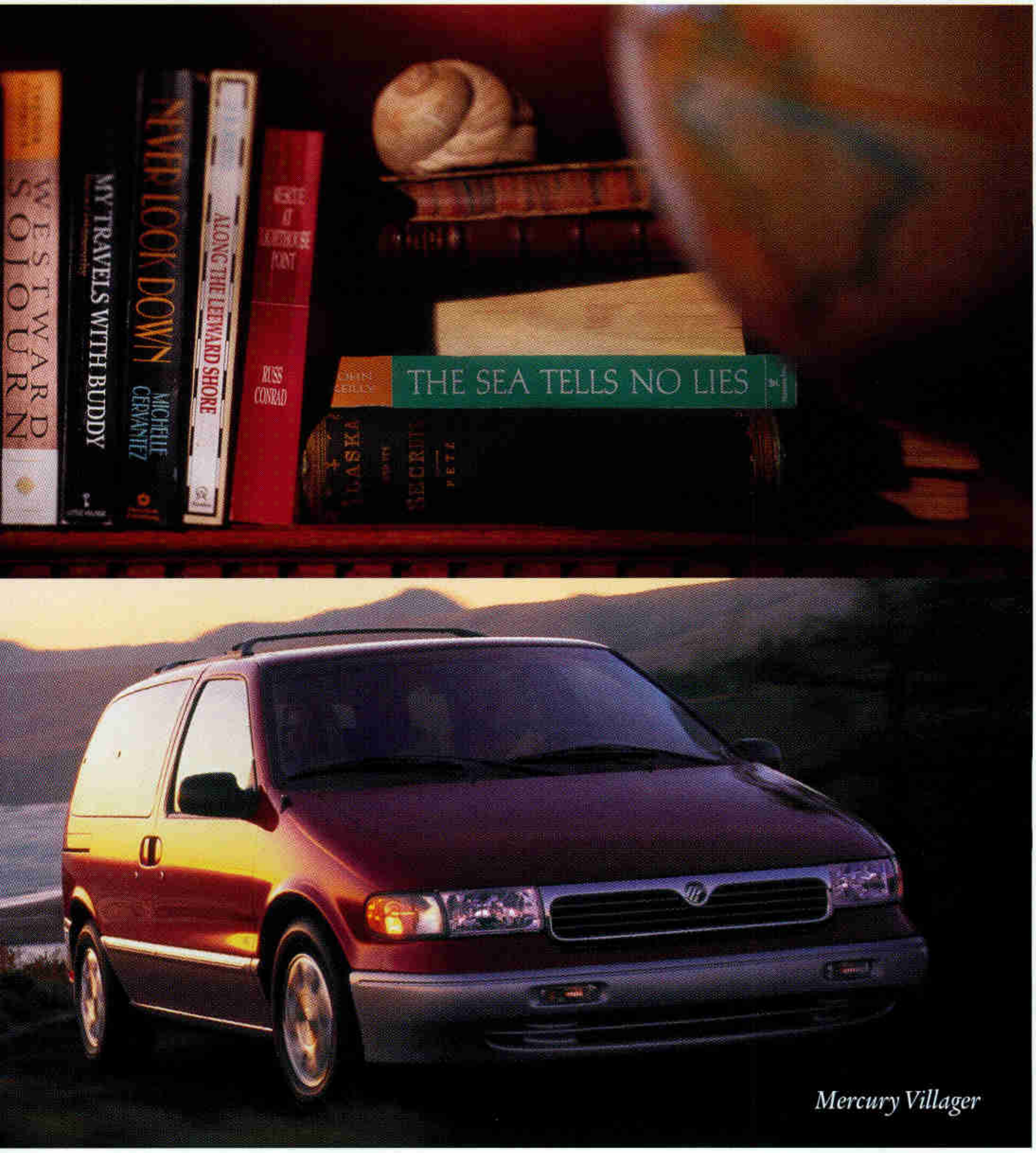


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fillings in my mouth is directly attributable, no doubt, to the amount of rock candy I had as a child. I have distinct memories of being carried from school on the shoulders of a chef from my parents' hotel because of the flooding caused by those monster waves from the Irish Sea. The article has saved me a fortune. I can show it to my kids instead of taking them there.

DAMIAN E. BUCKLEY
*Washington, D.C.*

The reference to the safety of Blackpool's bathing waters is worrying. I am the environmental protection officer for this area. While the local water company has spent over 200 million pounds (326 million dollars U.S.) on a sewerage scheme, three of four bathing beaches failed to meet minimum standards for bacterial quality in 1997. We are continuing an effort to identify the sources of these failures.

STEPHEN WREN
*Preston, England*

## Polar Bears

Again the GEOGRAPHIC has provided an interesting story with beautiful photography. It was mentioned that polar bears like to drink antifreeze from trucks, a common practice among animals. It is very toxic to the kidneys and can result in death. The state of Oregon now requires antifreeze manufacturers to add a bittering agent, denatonium benzoate, that is unpalatable to animals. It will also stop the bears from damaging trucks as they attempt to get at the liquid. I recommend that the proprietors of the Tundra Buggies procure this type of antifreeze.

TERRY A. BROCK
*Corvallis, Oregon*

I was disappointed to see the photograph of bear–human interaction (pages 64-5), even though the caption states that "all are admonished by guides to keep a healthy distance." The photo sets a bad example by glamorizing getting dangerously close and making visitors think they can get that close.

WENDY KEDZIERSKI
*Richmond, Virginia*

## Altamaha River

Thank you for printing the picture of the abandoned vessel *Lady Pamela* in Georgia's Altamaha River estuary. Although old vessels may be picturesque, this practice of dumping them in our nation's sloughs and waterways is a disgrace. They create dangerous hazards to navigation, contribute to pollution, and degrade the environment. In California it has long been illegal to abandon a vessel anywhere in the state's waterways.

Federal, state, and local entities have cooperated in Project Aqua Terra to facilitate the cleanup of a hundred derelict vessels in our area. Your photograph will help focus attention on this corruption of our environment.

ROBERT J. HOFFMAN
*Redwood City, California*

If you would like to know more about the Altamaha area as it was 150 years ago, find a copy of *Journal of a Residence on a Georgian Plantation,* by Fanny Kemble Butler. A famous English actress, she married Pierce Butler of Philadelphia, who owned a plantation on Little St. Simons, where they lived from 1838 to 1840. The London *Times* published her letters about the cruelty of slavery as she observed it, and the couple subsequently divorced.

MILDRED WACHTER
*Port Orange, Florida*

The photographs brought to my mind the poetic imagery of Sidney Lanier's "The Marshes of Glynn." My atlas shows a Glynn County on the south side of the Altamaha. Ever since I first read the poem, I have had the most vivid mental pictures of its setting, and now I can compare them with something that must be pretty close to Lanier's original: the rosy colors of twilight, the tranquil sunset over the river's mouth, the waves of marsh grass; they are all there in Peter Essick's beautiful photographs.

GALEN TACKETT
*Fremont, California*

Little Buzzard Creek, shown on the map on page 79, is one means of accessing one of the most remarkable sights on the lower Altamaha, the old-growth cypress stand on Lewis Island. This impressive stand of about 50 trees is the only known grove of tidewater virgin gum cypress in Georgia.

NEWTON QUANTZ
*Atlanta, Georgia*

One of the gems of the horticultural world, *Franklinia alatamaha* is a beautiful flowering tree with large white blooms in September. It is reputed to have grown wild on the banks of the Altamaha and to have been discovered and propagated by Benjamin Franklin. It is no longer found in its original haunts but is now enjoyed in many gardens.

ROBERT E. JACK
*Greenlawn, New York*

*It was discovered and propagated by botanists John and William Bartram (pages 76 and 79), who named it for their friend Franklin. Historic Bartram's Garden in Philadelphia is now taking a worldwide census of* Franklinia; *see www.libertynet.org/~bartram/.*

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*Letters for* FORUM *should be sent to National Geographic Magazine, Box 98198, Washington, D.C. 20090-8198, or by fax to 202-828-5460, or via the Internet to ngsforum@nationalgeographic.com. Include name, address, and daytime telephone. Letters may be edited for clarity and space.*

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NATIONAL GEOGRAPHIC
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## Radar Locates a Buried Past

Poring over radar images generated on space shuttle flights, researchers seek potential archaeological sites in the Gobi desert in southern Mongolia. "The images allow us to see buried stream channels invisible on the surface," says John W. Olsen of the University of Arizona, who works alongside U.S., Russian, and Mongolian scientists. "They're a clue to past ecological conditions and living sites."

With the radar images provided by NASA and the image-processing software company ERDAS, Olsen's group located several sites that yielded stone tools, as yet undated, created by early humans in a region long thought to be too arid for settlement. Datable stone tools and other evidence found in a cave indicate that it had been lived in intermittently for at least the past 125,000 years. "This cave offered easy access to water, game, and stone for tools—basic magnets drawing people there time and again," Olsen says.

JOHN W. OLSEN

KARL-ERIC SVÄRDSKOG

## The Swedish Nightingale Lives On

She was covered with dirt and cobwebs and had a hole in her abdomen, but when antique dealer Karl-Eric Svärdskog of Göteborg, Sweden, cleaned her up after she was found in a barn outside the city, he thought she was a saint. "Who created you, and where did you come from?" he wondered.

Now Svärdskog believes the five-foot-six-inch carved and painted figure (left) represents Jenny Lind, the 19th-century singer known as the Swedish Nightingale. It was, he says, the figurehead from the American clipper *Nightingale*, named for Lind and built in Portsmouth, New Hampshire. Experts on figureheads say it is impossible to be sure, but her hair and clothing style, her wood—North American larch—and that hole for a securing bolt all suggest he may be right.


*Nightingale* sank in the Atlantic in the 1890s. But Svärdskog learned that the ship had been converted to a bark in southern Norway in the 1880s, so her figurehead could have been removed then. How it got to a farm in Sweden, where it served as a scarecrow before being stored in the barn, is unknown. Lind remains a Swedish heroine, even adorning the nation's currency (above).

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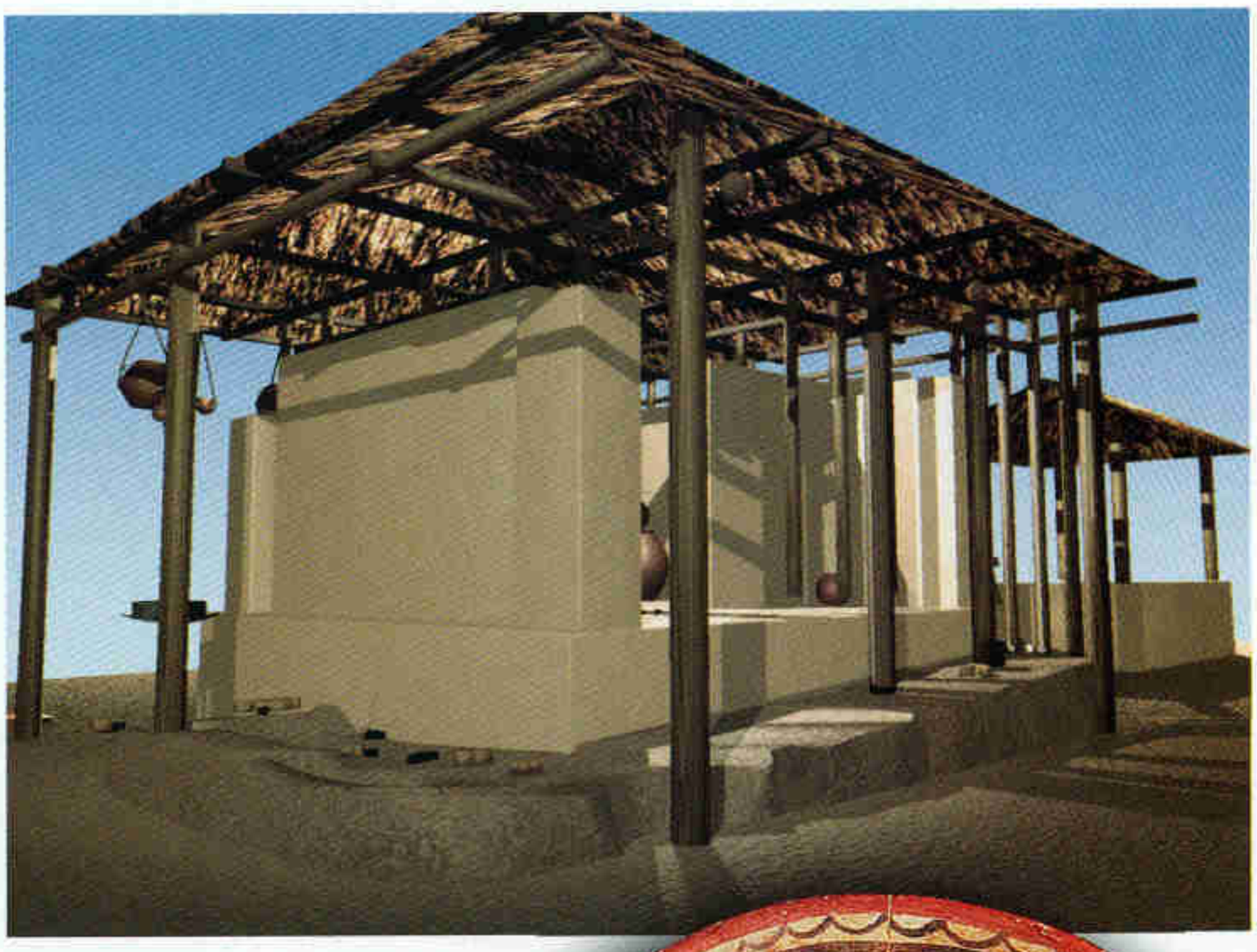
PEACE OF MIND

## Ancient Menu Dug Up in El Salvador

A volcanic eruption 1,400 years ago sent residents of the Salvadoran village of Joya de Cerén fleeing before it buried their thatch-roofed homes under 16 feet of ash. Everything left behind lay untouched until archaeologists led by Society grantee Payson Sheets began to unearth this New World Pompeii. Now an analysis of food and other items from the homes (right, in a computer reconstruction) provides a detailed view of the Maya villagers' lifestyle. They ate corn, wild and domesticated beans, and squash, spiced up meals with an array of chilies, cooked food in cottonseed oil, and wove cotton cloth that they probably traded for obsidian.



"These humble villagers had a very good life, probably better than that of the people living there today," says David Lentz of the New York Botanical Garden.

Evidence comes largely from seeds, such as this one from a chili pepper (electron micrograph, above left), found in vessels like the serving bowl at right, whose crab image shows another item on the Cerén menu. Lentz was surprised to find cacao seeds in abundance. "Historic accounts tell us that chocolate was a drink for the wealthy, but the ordinary people at Cerén had all they wanted."

JEN LEWIN, SUNDANCE LAB, UNIVERSITY OF COLORADO (TOP RIGHT); DAVID LENTZ (TOP LEFT); PAYSON SHEETS, UNIVERSITY OF COLORADO

## Decoding How a Worm "Works"

Barely visible to the naked eye, this tiny worm stars in a major effort: By the end of the year researchers will finish deciphering its entire genome, the first time science will have all the genetic information about how an animal reproduces, grows, eats, moves, and performs the myriad functions of a living creature.

"It's like doing a huge jigsaw puzzle," says John Sulston of England's Sanger Centre. His lab and that of Robert Waterston at Washington University, St. Louis, are unraveling the secrets of *Caenorhabditis elegans*. The numbers are awesome: Each of the worm's thousand cells has the same 17,000 genes and 100 million base pairs of DNA. Since many of its genes have human counterparts, researchers may more easily study mutations and learn the causes of genetically based human diseases.

CHRIS LINK, UNIVERSITY OF COLORADO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## Wooden Indians, and a Host of Others Too

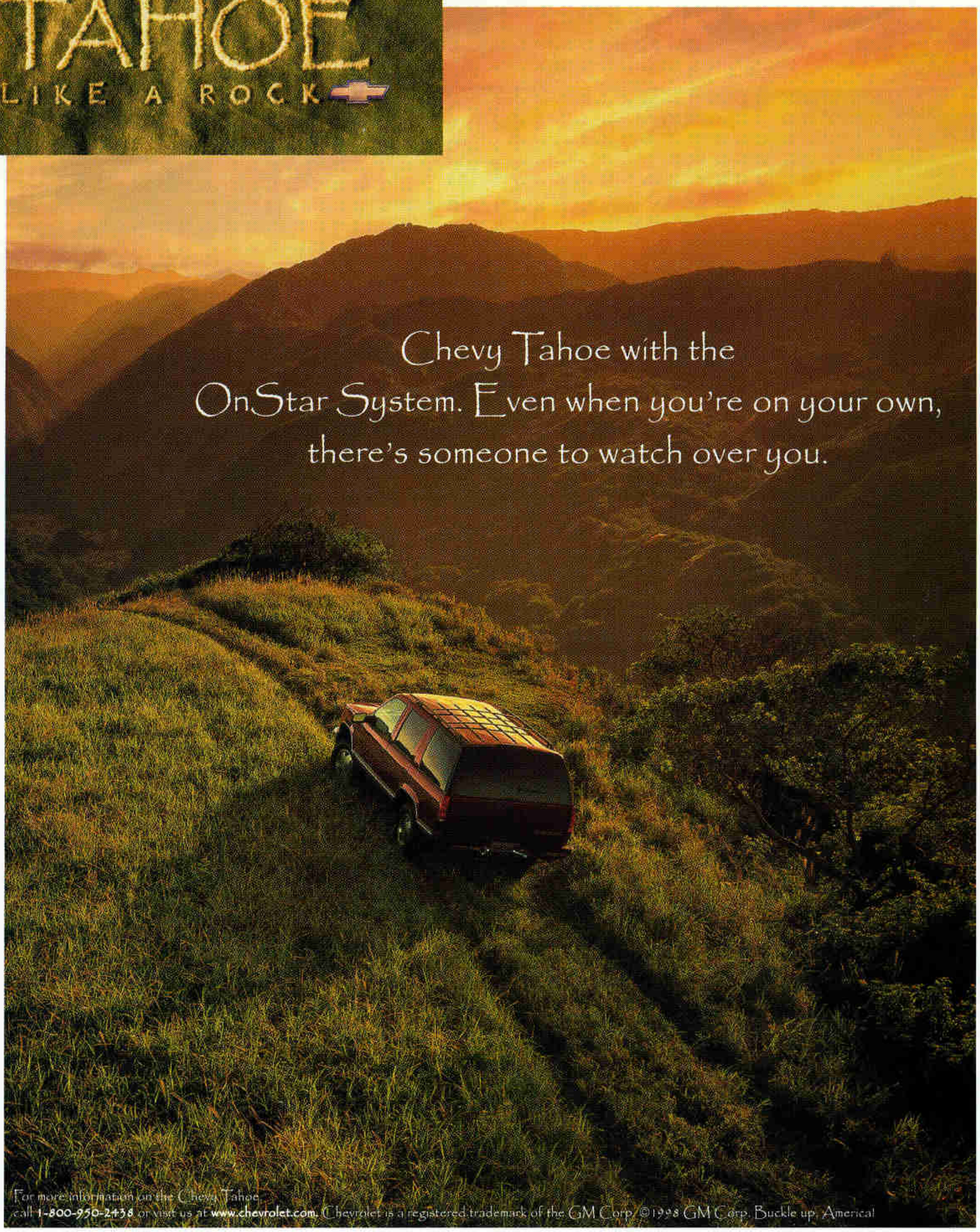
Anyone who walked through a U.S. town in the 19th century would have recognized these shop figures. Usually crafted of wood by ship carvers who branched out from creating figureheads and thought of themselves as being in the "image business," the shop figure was a landmark, a piece of advertising, a silent shout to a passerby.

Between the 1840s and the 1890s, the peak of their popularity, "they were everywhere," says Ralph Sessions, curator of an exhibit of 60 such shop figures at the Museum of American Folk Art in New York City. "The idea was that if a store had a great or interesting figure, it would attract attention, and people would come in."

The most famous figures were "cigar store Indians," such as the "Indian princess" (far right), who linked tobacco and Native Americans in the popular mind. One tobacconist lamented that his figure cost as much as his stock. Carvers created a wide-ranging cast of characters, as seen here, from left: the racetrack tout; the Turk, also associated with tobacco; Father Time; and the firefighter, this one commemorating Columbian Engine Co. 14 in New York City.

"It became a real fad," Sessions says. "They depicted all sorts of characters: baseball players, theatrical stars, politicians." And many figures reflected the stereotypes of the times, notably the happy-go-lucky African American and the American Indian seen as a "noble savage." "These figures were carved out of American popular culture, which was mainstream Anglo-American," Sessions says. "What we consider derogatory now was more acceptable then."

Eventually the custom ran its course. The ranks of ship carvers shrank as metal-hulled vessels, without figureheads, replaced wooden ones. Painting and maintaining a shop figure was expensive. New types of ads, primarily color lithographs, could be created cheaply and changed whenever advertisers wanted to deliver a new message. Shop figures were seen as old-fashioned images from an earlier, vanished America. By century's end, the carved shop figure was fading into obscurity.

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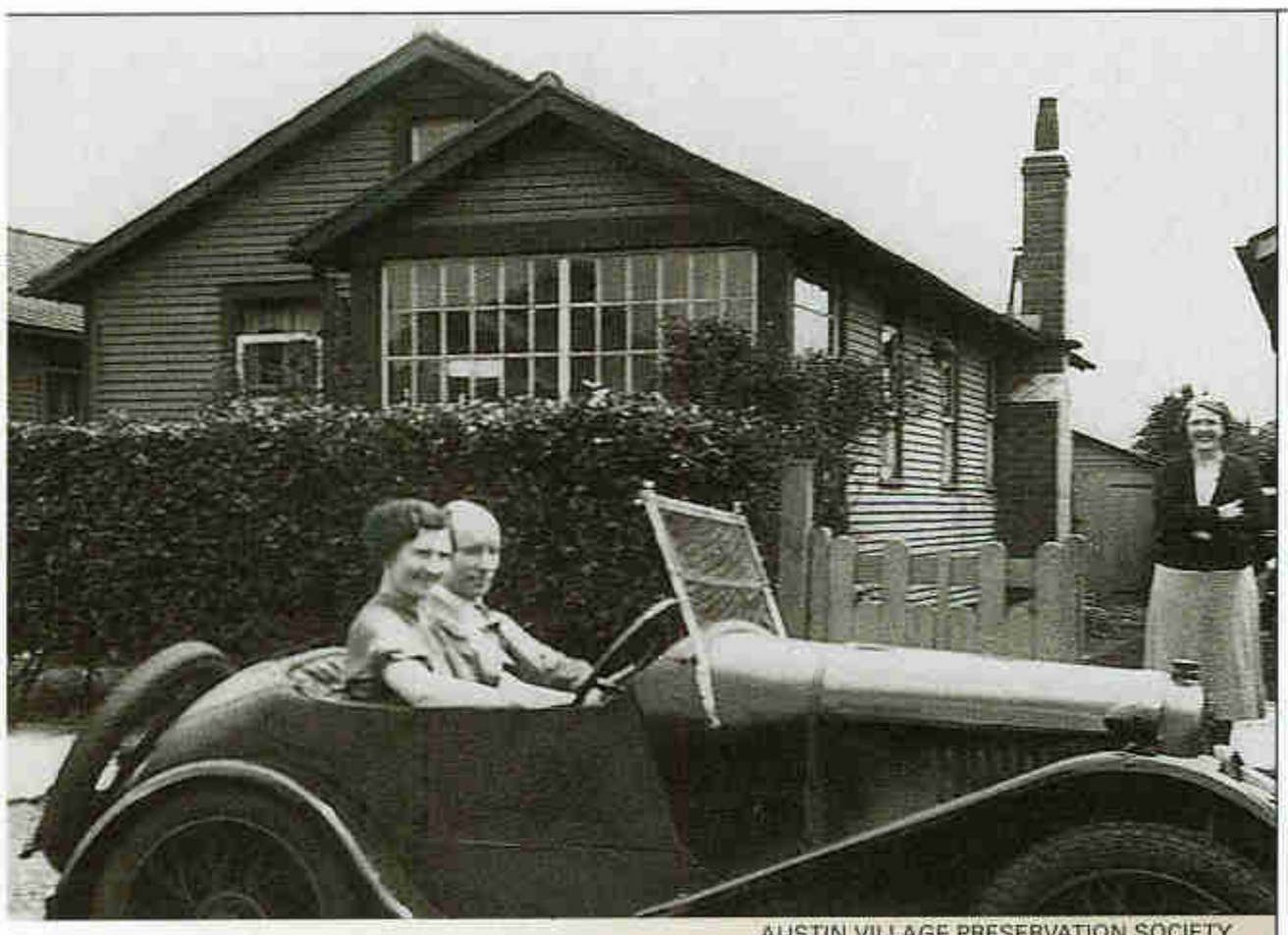


AUSTIN VILLAGE PRESERVATION SOCIETY

## Temporary English Homes Last and Last

Herbert Austin's small auto factory outside Birmingham, England, grew tenfold in World War I when it switched to munitions-making. Desperate to house his workers, he erected 200 prefabricated cedar houses imported from Aladdin Homes in Bay City, Michigan. Nervous authorities issued a mere five-year "fit for habitation" license for the homes in 1917.

STUART FRANKLIN

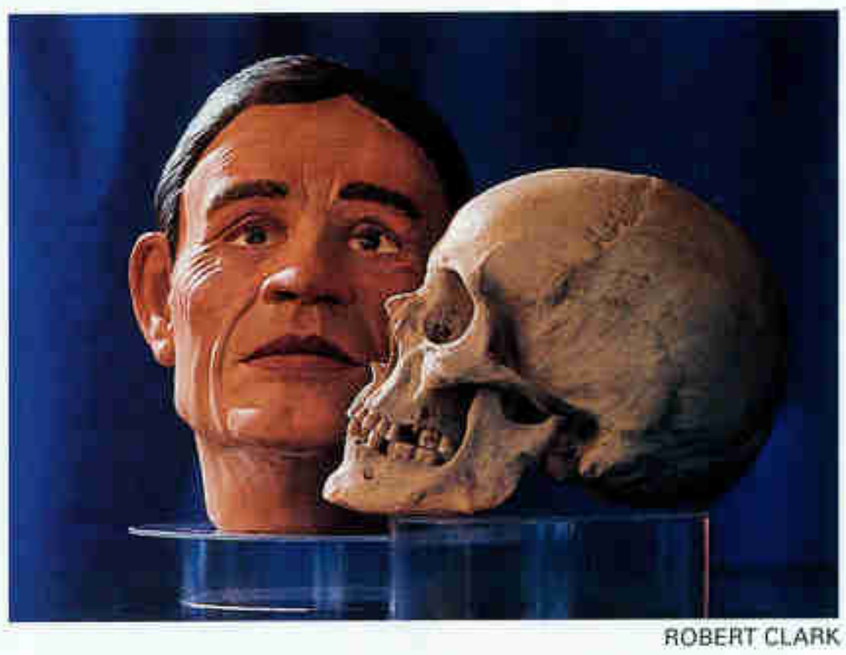
Last year Austin Village won conservation status; changes in the appearance of the homes must be approved by municipal officials. That pleases long-time residents like Arthur White and his neighbor Rita Walters (above), whose mother sat at the wheel in front of her bungalow decades ago (top). Says George Drywood of the Austin Village Preservation Society, "The condition, with central heating and indoor bathrooms, is as good as it was in 1917."

## Shipwreck Victim Gains a Face

Putting a face on history, experts have created a realistic bust (below) based on the skull of an unknown sailor who toiled on the *Belle*, ill-fated flagship of French explorer Sieur de La Salle (GEOGRAPHIC, May 1997). The sailor's complete skeleton was found atop sodden rope in the bow of the *Belle*, which sank in Matagorda Bay in Texas in 1686.

To produce a resin model of the fragile skull, specialists used an extraordinarily precise CT scan and ultraviolet laser. After moving through a series of casts and molds, they painted a white plaster-of-paris cast with coloring thought to be characteristic of a sailor from Normandy.

"This helps us make his story more personal, make it real," says Donny Hamilton, a Texas A&M University nautical archaeologist. "We're giving him an identity." Researchers hope to make it even more personal by learning the sailor's name and role on the ship.



ROBERT CLARK

PETER DE SÈVE

## Buyers Link Wine, Geography, and Song

Hear the tune, buy the wine?

For two weeks, music blared in an English supermarket above displays of comparable bottles of French and German wines. Nearby, a team of University of Leicester psychologists monitored buyers' choices. When French accordion music played, French wine outsold German varieties by a five-to-one ratio. But when German beer-hall music oompahed, buyers bought two bottles of German wine for every French bottle. Only a few buyers admitted—or were even aware—that music played a role in their decision, says researcher Jennifer McKendrick. "If you go in to buy a specific item, music won't affect your choice," she says. "But if you're uncertain, music could be an influencing factor."

TEXT BY BORIS WEINTRAUB

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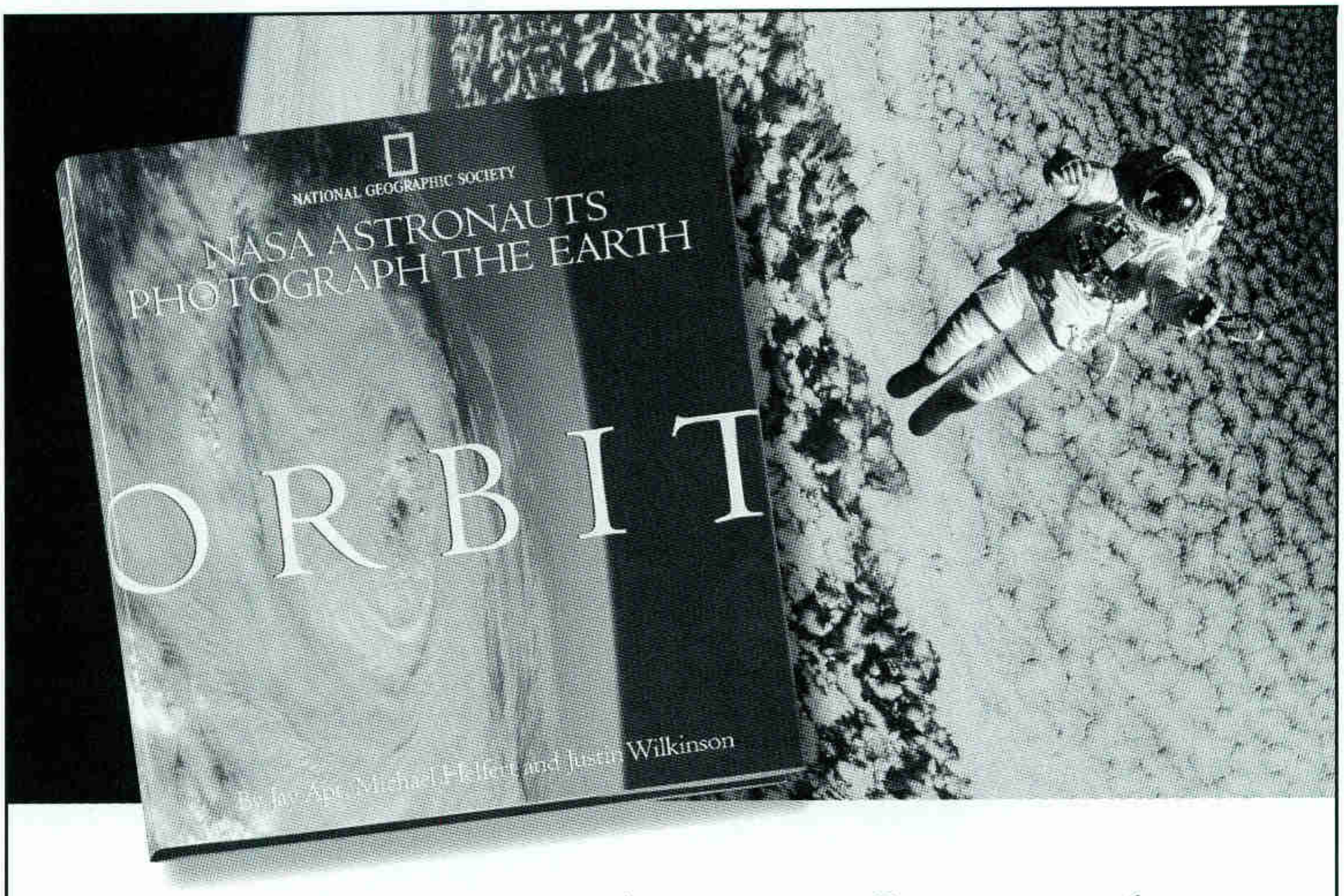


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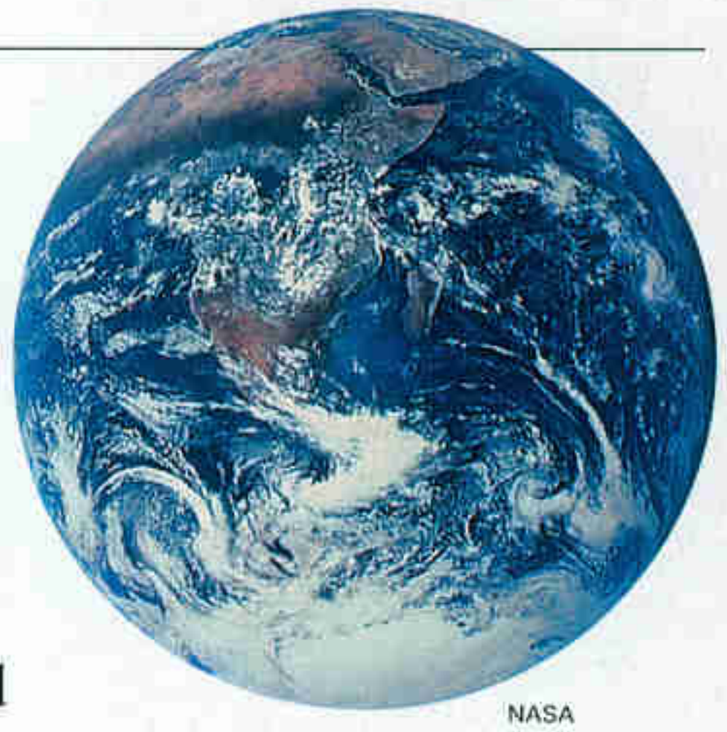

NASA

## From the Editor

AMONG SCIENTISTS around the world, the study of our planet's climate surely ranks as one of the most highly charged fields of modern inquiry. Humans and all other species on Earth live—and often die—in direct response to climate, and we're still striving for sure answers to the basic questions about this extraordinarily complex system: How and why does our climate change?

Now, as the new millennium approaches, another question weighs heavily: How much does *our* activity on the planet contribute to climate change?

In 1995 the Intergovernmental Panel on Climate Change (IPCC) stated that Earth is warming. What caught the world's attention, though, was the conclusion that part of this warming is unnatural—caused in large measure by our burning of oil and coal, which increases the volume of greenhouse gases in the atmosphere. The IPCC report galvanized heads of state and policymakers around the world, who last December in Kyoto framed an unprecedented accord that would oblige the industrialized nations to reduce their total emission of greenhouse gases to 5.2 percent below the 1990 level by 2012.

Among scientists and nonscientists alike, many say it's now a given that human-induced warming threatens to disrupt life on Earth. On the other side of the debate people deny that such warming is taking place at all. One thing seems certain: The debate will rage as long as the evidence is in any way equivocal. For instance, measurements of air temperatures over the past century show warming near Earth's surface. But some data from satellites and radiosonde balloons over the past several decades indicate a cooling in the lower atmosphere. Until these apparently conflicting records are reconciled, they provide fuel for both camps.

Our article this month about climate change encompasses both the human element and the day-to-day effects of weather extremes. But we also show that over geologic time—and with no human influence—Earth's climate has repeatedly swung back and forth between cooler and warmer. Our synthesis of current understanding about climate change comes with one caveat: Every day, it seems, scientists publish some new insight into the complexity of the climate system, which despite the explosion of knowledge in recent years remains, frustratingly, mysterious.

Bill Allen

# PHYSICAL

## How will the planet change?

■ Tranquil remains of a colossal eruption 7,700 years ago, Oregon's Crater Lake marks a region that endures a geologic upheaval about once a century.

# WORLD

By **Joel L. Swerdlow** ASSISTANT EDITOR

JIM RICHARDSON


**For more on the millennium, visit www.nationalgeographic.com.**

HILLS ROLL IN ALL DIRECTIONS. Below me is a winding stream and tree-covered valley. Above, clouds drift in a deep blue sky. I have loved this countryside, just south of Syracuse, New York, since childhood. But the permanence I took for granted growing up here is a matter of perspective. Beneath me a plate of rock about 25 miles thick moves northwest at the rate of an inch a year as the Earth's crust recycles itself. At least four times during the past two million years ice has crept down from Canada. The grayish brown rock beneath my feet is full of fossil shells that are hundreds of millions of years old—evidence of the huge inland sea that once covered this land. ■ Scientists use such geologic clues to decipher the story of the physical world. In Rick Gore's "Cascadia: Living on Fire," dead cedars standing in salt water, oceanic sand carpeting a forest floor, and mollusks locked in an island cliff bespeak a world in constant motion. ■ These and other oddities have convinced experts that much of the Pacific Northwest is a major fault zone where serious earthquakes or volcanoes could occur at any time. "A geologic time bomb waiting to go off" is what Don Hull, the Oregon state geologist who is mentioned in Gore's story, calls his home state. ■ I phone Hull and learn that he's just back from Pompeii, the ancient Roman city destroyed by a volcanic eruption in A.D. 79. "Those folks weren't paying attention to their geology," he says. Residents of Pompeii did not realize that more than 15 years of earthquakes meant an eruption was imminent. ■ "What does it mean to pay attention to your geology?" I ask. "Should we all be worried about earthquakes and volcanoes?" ■ "No," he says. "In the United States, at least, we've found many of the major active faults." But then he reminds me that a fault system does run from Arkansas up to Illinois in what most people think of as a seismically stable region. In the early 19th century an earthquake centered in New Madrid, Missouri, made church bells ring in Richmond, Virginia. ■ Hull sounds confident when he says that most Americans need not worry about earthquakes and volcanoes. Still, Oregonians didn't know until less than two decades ago that they were vulnerable to massive tremors. The physical world has plenty of other surprises for us, none more significant than those outlined in Curt Suplee's story on climate change. ■ Atmospheric chemicals trapped in ice a thousand feet

**an inert statue, is a living mobile thing.**

—J. TUZO WILSON, GEOLOGIST, 1968

beneath Tibet's surface, shells in mud at the bottom of ancient lakes in Yucatán, and other hidden records all offer evidence that climate changes according to natural cycles—and that such change can be swift and dramatic. What is new is that for the first time humans may be altering Earth's climate. ■ Belief in this possibility has existed since at least 1896, when Svante Arrhenius, a Swedish chemist, predicted that burning fossil fuels could warm the planet through a greenhouse effect—a phenomenon first recognized by French mathematician Joseph Fourier in 1824. ■ Warming has indeed occurred. The global average air temperature has risen one degree Fahrenheit over the past hundred years, and since 1980 we've experienced the 13 hottest years on record. All this could intensify weather, leading to floods and drought, as well as the spread of insect-borne tropical diseases such as malaria. ■ Growing evidence shows that our use of fossil fuels contributes to warming. But what about the warming fueled by natural cycles? Could it account for the problems we attribute to our own actions? ■ I put that question to Jeffrey Kiehl, a climate scientist at the National Center for Atmospheric Research. "Some global warming may be normal," he says. "But warming could also be accelerated by humans." ■ Kiehl helped design one of the latest computer models for predicting changes in climate. Such models are essential because inaccurate predictions from the 1980s, when scientists lacked the capacity for organizing massive amounts of data, have bred confusion. In 1983, for example, some experts suggested that global warming would raise sea levels as much as seven feet over the next century. Computer models now indicate the maximum increase in sea level will be less than two feet. ■ "Warming caused by humans could be quite large compared with natural warming," Kiehl says, adding that it will take ten to twenty more years to show with certainty whether or not there is human impact on climate. Even then, he says, "people usually need some sort of disaster to drive them into action." ■ I think back to what Don Hull told me when he returned from Pompeii: "Those folks weren't paying attention to their geology." As science continues to solve the mysteries of the physical world, we will be better prepared than they were. But will we pay attention? And will we take whatever actions may be necessary, even though science can't tell us precisely what those actions should be? □

*In anticipation of the turn of the millennium on January 1, 2001, NATIONAL GEOGRAPHIC is spotlighting six subjects that will shape human destiny. Articles in this issue examine the changing Earth. The series continues in October with a focus on population.*

The Millennium Series

# CASSCC

# LIVING

BY RICK GORE
SENIOR ASSISTANT EDITOR

# A D I A

# ON FIRE

PHOTOGRAPHS BY JIM RICHARDSON

**DANGER LURKS IN THE CASCADES,** THE VOLCANIC RANGE THAT BRISTLES BETWEEN NORTHERN CALIFORNIA AND BRITISH COLUMBIA. MANY PEAKS ARE STEAMING AND COULD ERUPT LIKE WASHINGTON'S MOUNT ST. HELENS, WHERE VISITORS COMPARE THE CONE WITH A PHOTOGRAPH TAKEN BEFORE ITS 1980 BLOWOUT. NEARBY MOUNT RAINIER (PRECEDING PAGES) AND OTHER PEAKS COULD SEND TORRENTS OF MUDDY DEBRIS DOWN THEIR SLOPES. IN ADDITION, MASSIVE EARTHQUAKES MAY CAUSE TSUNAMIS TO CRASH INTO TOWNS SUCH AS CANNON BEACH, OREGON (BELOW). EACH OF THESE EVENTS HAS TRANSFORMED THE REGION MANY TIMES BEFORE—AND COULD HAPPEN AGAIN IN AN INSTANT.

## FIRE AND ICE

Snowy spires that stretch northward from Oregon's Three Sisters to Mount Rainier belie the red-hot magma that built them and still simmers below. Part of the Pacific Ring of Fire, these volcanoes are the heart of an 800-mile-long arc that marks the slow, grinding descent of an oceanic fragment of Earth's outer shell beneath North America—a process called subduction. Beacons for early explorers and settlers, the stunning peaks are attracting ever more residents to Cascadia.

"I NEED TO TELL YOU about the etiquette of fire walking," says Ariel Frager, a serene, raven-haired woman in her 20s. She is speaking to a group of rain-soaked spiritual adventurers who have gathered at Breitenbush Hot Springs, a retreat in the foothills of Oregon's Cascade Range. It's almost midnight, and as Ariel speaks, the glow from the hundreds of red-hot coals we have raked into a 12-foot-long path radiates across her face.

"Walk with purpose," she tells us. "Be mindful of the others ahead of you on the coals. Breathe deeply. And always respect the fire. Otherwise, you're going to get burned."

Fire walking has become a popular ritual along the West Coast. "It teaches you to overcome your fears and do what you thought was impossible," Ariel's appropriately named co-leader, Heather Ash, says. "In the past this opportunity was given only to medicine men, priests, and shamans."

My fellow fire walkers have gathered here for various reasons. A skeptical firefighter from the Willamette Valley wants to learn what the trick is. Others seek inner renewal. Some are here on a whim: "I want to get rid of a wart on my foot," quips a young man from Breitenbush.

I am here as part of a geologic quest. Intense fires burn beneath this stretch of the Pacific Northwest that geologists call Cascadia, after the chain of Cascade volcanoes that includes Mounts Shasta, St. Helens, and Rainier. Cascadia begins about 200 miles north of San Francisco and ends along the north coast of Vancouver Island (maps, pages 20-22).

The geologic turmoil beneath this 200-mile-wide sliver is created mostly by a slab of ocean crust known as the Juan de Fuca plate, which is subducting, or diving beneath the continent, along a zone of faults off the coast. As that plate subducts, it triggers the melting of deep-seated rocks into magma, which rises to the surface to form the range of Cascade volcanoes.

The plate can also subduct in a sudden lurch, producing a powerful earthquake. Geologists have recently realized that such earthquakes can exceed magnitude 9 and send 40-foot-high waves known as tsunamis crashing onto the coastline. As Oregon's state geologist, Don Hull, told me in Portland: "We've got Godzilla sleeping under us."

Since the residents of Cascadia are walking on fire geologically, I can't resist joining a group of them to actually do it. When my turn comes, I take a deep breath. Twelve steps later I am off the coals, heaving with relief and unburned.

The next morning we wonder how we could have walked those 1200°F coals unscathed, but we simply don't know enough about the science involved. In that way we are like the geologists who are grappling to understand the many unknowns that keep the fires beneath Cascadia burning.

My interest in Cascadia began four years ago, while I was working on an article about California's San Andreas Fault.* I had driven with Gary Carver, a geologist at Humboldt State University, through windswept ranchland along California's north coast to see where the San Andreas ended. We crossed a grand and lonely landscape. Mountains seemed to surge out of the blue sea, tumbling inland from aprons of isolated beaches. Finally we caught sight of a 326-foot-high coastal rock called Sugarloaf Island, the westernmost point in California and the first landmark of Cascadia.

"We've left San Andreasland," said Carver. "From here north it's timbered forests, spotted owls, salmon, and rain—everything the Pacific Northwest is known for."

One thing the Pacific Northwest has not been well known for is earthquakes. Ask the many Californians who moved to Oregon thinking they had left earthquake country behind.

Native Americans knew better. A spirit called Earthquake survives in stories passed on by indigenous peoples throughout Cascadia. When I return to the region in 1997, Carver takes me to Big Lagoon, about 50 miles north of Cape Mendocino. We walk to the remnants of a Yurok village called Oketo.

"There was a sweat lodge here," says Carver, who has been researching native legends with his wife, Deborah. "One story tells how people came here in terror when they saw the ocean standing high like hills. They brought their woodpecker headbands, which they wore only when doing a jumping dance to ward off

*See "Living With California's Faults," by the author, in the April 1995 issue.

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This is photographer JIM RICHARDSON's 11th story for NATIONAL GEOGRAPHIC. He lives in the seismically stable state of Kansas.

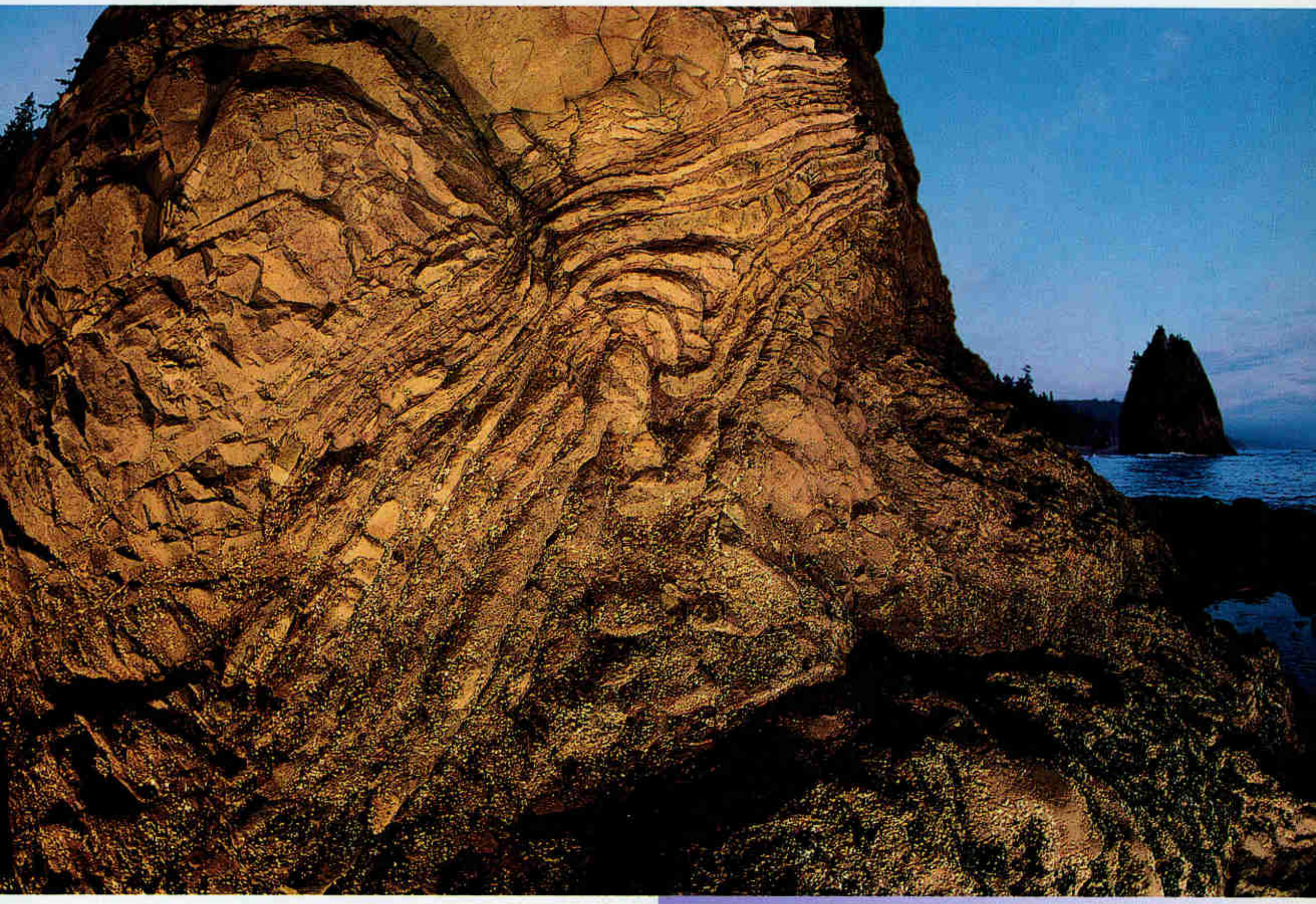
impending disaster. Soon waves were hitting the walls of the sweat lodge."

Since the sweat lodge was at least 30 feet above sea level, Carver is convinced that the Yurok were describing a tsunami that struck following an earthquake along the Cascadia subduction fault. Tsunamis are sometimes erroneously called tidal waves but have nothing to do with tides. The word "tsunami" means "harbor wave" in Japanese, and they are natural responses to earthquakes.

Such earthquakes occur when all or part of the subducting plate gets locked against the overlying plate, and strain builds. The seafloor plate subsides, while the land on the overlying crust slowly buckles upward. When the lock eventually breaks, the subsided seafloor rebounds, displacing many cubic miles of ocean in a series of tsunami waves. At the same time, the elevated land along the coast drops.

Until the mid-1980s there was no evidence that a subduction quake had ever hit Cascadia. Most scientists figured the Juan de Fuca plate was diving smoothly beneath the continent. Then a geologist named Brian Atwater began publishing disquieting evidence he had found in the coastal marshes of Washington State.

I MEET ATWATER at his campsite on the central Washington coast on a gray, lightly raining morning in June. He straps a canoe onto his pickup, and we drive with a team of students toward the estuary at Copalis Beach. Atwater, a self-effacing, bearded geologist with the United States Geological Survey (USGS) in Seattle, wants to show me his ghost forest.



## CREATIVE POWER

"You're looking at the growth of North America," says Ray Wells of the U.S. Geological Survey (USGS), describing rocks at Rialto Beach, Washington. These contorted layers were once mud and sand swept to sea by rivers. Offshore the sediments settled as a thick blanket on the ocean floor. But that floor was moving eastward and downward, subducting under the continent. Like a snowplow, the continent's edge scraped off the sediments to form this new land.

SECOND BEACH

Sentinels resisting the force of waves, sea stacks off the coast of Washington are all that remain of accreted sedimentary land that was fused onto the continent during subduction. At the end of the Ice Age, when glaciers melted, rising seas eroded all but the hardest rock.

At Copalis we put on hip waders and paddle deep into the estuary, stopping at a bank covered with grasses. We climb out of our canoe and trudge through sucking mud up the steep bank. Once on top we see an army of dead cedar trees, bleached and leafless, rising out of the marsh.

"They are quite out of place here," says Atwater. "Cedars don't like salt water, and here they have their feet in it. Until 300 years ago this would have been an upland. We would be looking at an old-growth forest. Then the land dropped at least a meter, and the upland became a tidal flat, killing the trees."

Atwater has also found evidence here for the tsunamis that followed the earthquake. He digs into the five-foot-high mudbank to show me an inch-thick band of oceanic sands sitting on top of dark soils typical of forest floors. Radiocarbon dating of tree roots in the soil shows that the trees died and the sand was laid down around 1700.

Since the discovery of the tsunamis in 1986 Atwater and other researchers have found similar evidence for this 300-year-old event all along the Cascadian coast, as well as evidence for many earlier subduction earthquakes.

Geologists have debated the size of those earthquakes. If the entire subduction-zone fault ruptured from northern California into Canada, it could create an earthquake of magnitude 9 or higher. If just a small part of the fault broke, the earthquake might be only an 8.

But thanks to the detective work of Kenji Satake, a tsunami specialist with the Geological Survey of Japan, many geologists now agree that the entire subduction zone ruptured

nearly 300 years ago. Satake found in local Japanese records that tsunamis struck the coast of Honshu, directly across the Pacific from Cascadia, on January 27 and 28 of 1700. Through a painstaking process of elimination, he ruled out all possible sources for the tsunamis other than an earthquake in Cascadia of magnitude 9. Then, calculating the time required for a tsunami to cross the Pacific, he determined that Cascadia's last great earthquake struck at about 9 p.m. on January 26, 1700.

Tree-ring scientists have since figured out when ghost-forest trees died along the Washington coast. The most exactly dated of these trees laid down their last ring in the year 1699.

How often do the big quakes recur? Seven centuries had elapsed between the one in 1700 and the one before it. But the two before those were only three centuries apart. Using satellite positioning systems that let them measure the distances between a number of ground-based antennas to within millimeters, geophysicists can actually watch the strain build beneath Cascadia. At the University of Washington scientists have determined that the tip of the Olympic Peninsula in the northwest corner of the state is moving northwest at about half an inch a year. As Tony Qamar, Washington's state seismologist, puts it: "The earth here is being compressed like a big spring."

To the north along the subduction zone at the town of Ucluelet on the west coast of Vancouver Island, Canadian scientists see a similar squeeze. Their ground-based satellite station is moving west at about the same rate. The coast there is also buckling upward at about a fifth of an inch a year. "Strain has been building for 300 years," says Garry Rogers of the Geological Survey of Canada as we gaze out over the Pacific from the peaceful shores of Ucluelet. "If the earthquake happened right now, we would quickly drop several feet and jolt ten feet seaward."

Along the coast, tsunamis would intensify the dangers of such an earthquake. To appreciate what those tsunamis would do, I drive Oregon's scenic coastal highway with Don Hull, the state geologist.

"After the great earthquake, there'll be a series of large waves," says Hull. "The first will arrive within 5 to 30 minutes, and we'd expect heights of 15 to 25 feet, but they could be much higher in places. Several more waves may strike over the next few hours."

Hull is taking me to a town meeting in Waldport, about midway along the coast. Bonnie Conrad Dunn, a port commissioner there, had called his office after learning of past tsunamis in nearby wetlands. Alarmed, she had mustered community leaders to discuss the need for tsunami emergency plans.

"It comes from my old Girl Scout training," she tells me when I meet her in Waldport. "Be prepared."

At the meeting Hull explains steps that can be taken by this town, which has an average elevation of 12 feet above sea level and two schools that sit on a floodplain. Critical facilities can be built high enough to stay dry. Tsunami warning signs can be posted along the beaches. Evacuation drills should be conducted, especially in low-lying schools.

**IN HARM'S WAY**

It's the law in Oregon: All schools on the coast must conduct periodic safety drills. At Cannon Beach students duck for cover in earthquake practice; next they hurry to a nearby hill beyond the range of tsunamis.

Orting, Washington, faces risk from Mount Rainier. "There's more to it than an eruption," says evacuation planner Scott Fielding. The stump beneath him belonged to a tree felled by a Rainier mudflow 500 years ago and dug up during construction of new houses.

**Key Events**

Earthquake

Volcano

Tsunami

**1700, Cascadia earthquake, magnitude 9**
The entire subduction zone, from Vancouver Island to Cape Mendocino, probably ruptured, creating tsunamis that hit Japan.

**1946, Vancouver Island earthquake, M 7.3**
The largest onshore earthquake in Canadian history was felt as far south as Portland, Oregon.

NATIONAL GEOGRAPHIC MAPS
DIGITAL MAP SOURCE:
RALPH A. HAUGERUD, USGS

Scale varies in this perspective.

Mt. Meager 8,793 ft

Mt. Cayley 7,792 ft

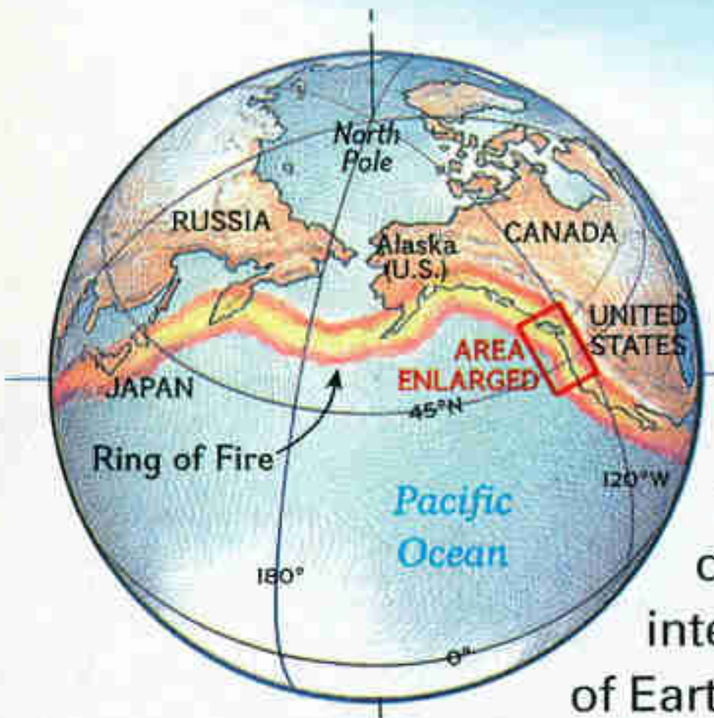
Strait of

Vancouver Island

Ucluelet

Nootka Island

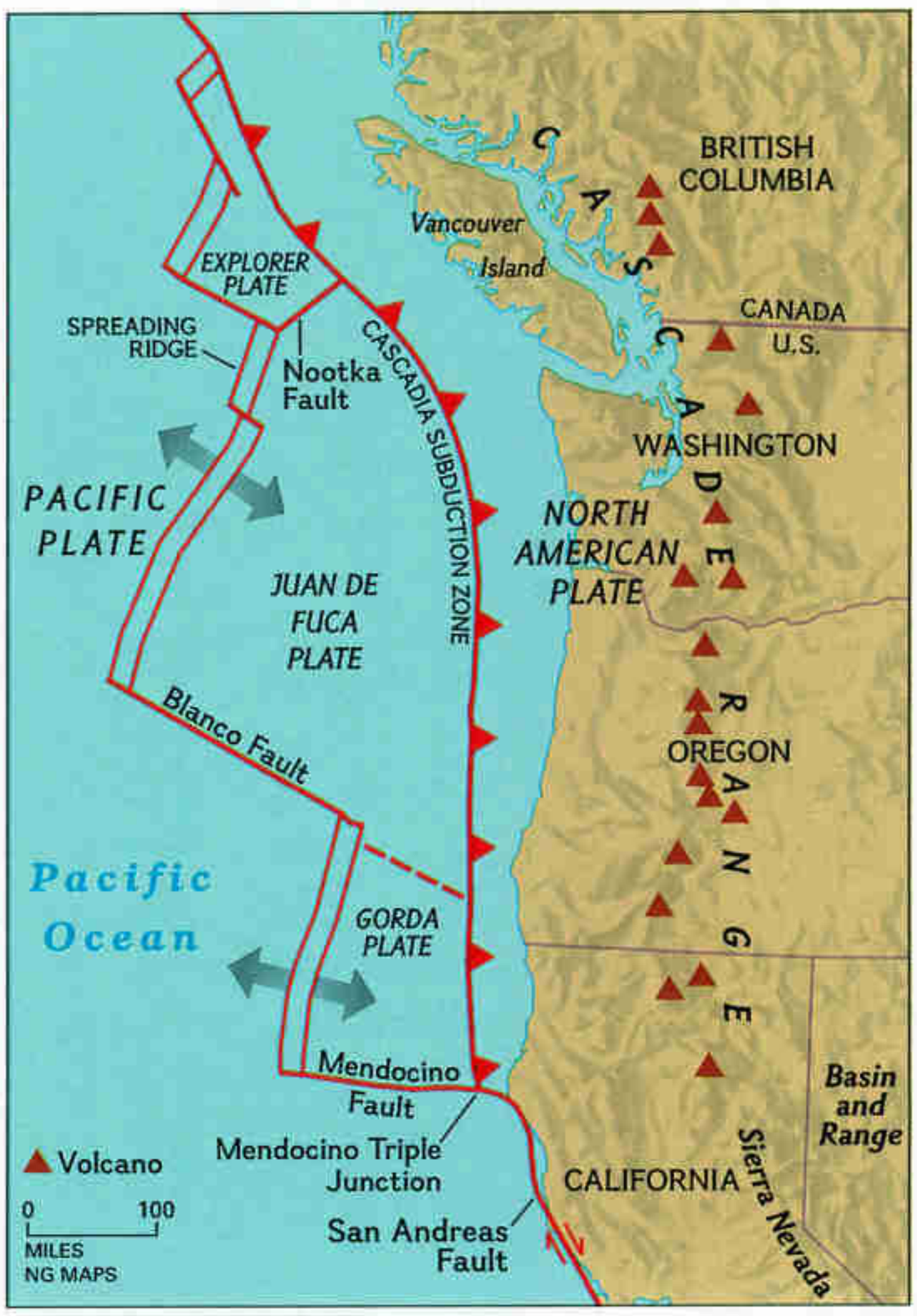
JUAN DE FUCA PLATE




# ETERNAL UNREST

A sobering array of hazards results from the movement of tectonic plates, the interconnected pieces of Earth's crust. In Cascadia the subduction of the Juan de Fuca, Gorda, and Explorer plates causes devastating earthquakes and tsunamis every few centuries and creates the range of volcanoes that gives the region its name.

Though the same process stokes geologic fires around the Pacific Ocean, this subduction zone has unique complications. Edging toward Vancouver Island, the Juan de Fuca plate drags at North America, causing earthquake-prone fractures. Another source of stress: The Pacific plate's shift northwestward along the San Andreas Fault forces Oregon into Washington. Adding to the pinch, the Basin and Range area is pushing from the east. The calamities cited here (top) are but a fraction of what these forces have wrought over many millions of years.



**1872, North Cascades earthquake, M 7.4**
This is the largest crustal earthquake ever recorded in Washington or Oregon.

**1949, Puget Lowlands earthquake, M 7.1**
Shaking was felt across 150,000 square miles. The parts of Seattle and Olympia built on fill were especially affected.

**3600 B.C., Osceola Mudflow**
Mount Rainier's summit collapsed, creating mudflows in places 700 feet deep that reached Puget Sound 65 miles away.

**1980, Mount St. Helens eruption**
The largest Cascadia blast in two centuries scoured 200 square miles, killed 57 people, and choked nearby towns with ash.

**1993, Scotts Mills earthquake, M 5.6**
In ground many presumed stable, the initial quake and aftershocks caused 30 million dollars in damage.

**5700 B.C., Mount Mazama eruption**
Once 12,000 feet high, Oregon's Mount Mazama collapsed in a cataclysmic blast, forming Crater Lake.

**1964, Tsunamis**
A subduction zone quake off Alaska, M 9.2, gave rise to tsunamis that also heavily damaged Vancouver Island and Crescent City, California.

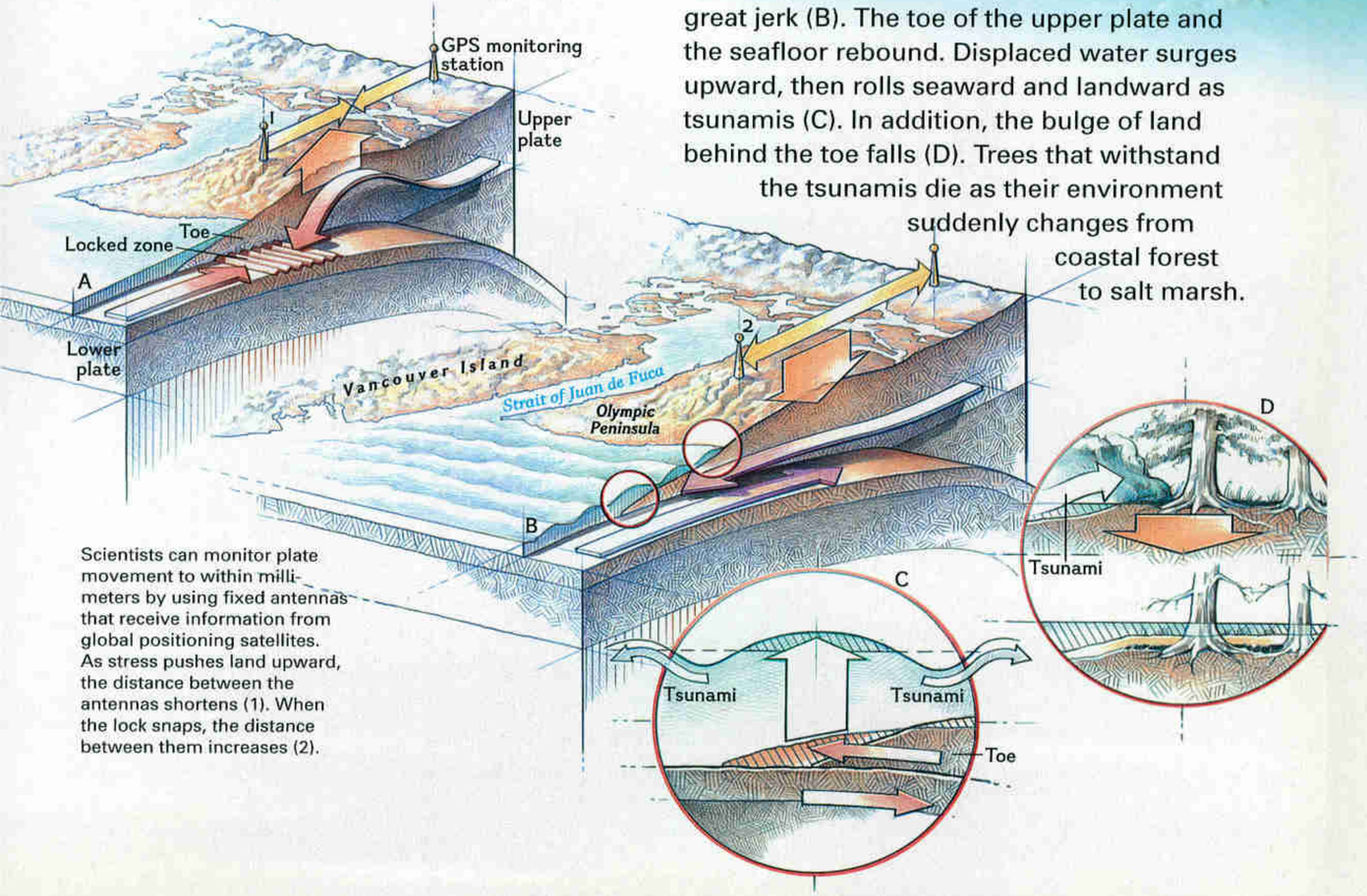
**1992, Petrolia earthquake, M 7**
Geologists debate whether this event that produced coastal uplift of four to five feet was a subduction quake.

**1914-17, Lassen Peak eruption**
Black-ash clouds signaled the opening of a vent, which became a new crater. Many subsequent eruptions resulted in lava and mud flows.

Mt. Garibaldi 8,787 ft
Mt. Baker 10,785 ft
CANADA U.S.
Glacier Peak 10,541 ft
Mt. Rainier 14,410 ft
Columbia
Mt. St. Helens 8,366 ft
Mt. Adams 12,307 ft
WASHINGTON
OREGON
Mt. Hood 11,239 ft
Three Fingered Jack 7,841 ft
Mt. Jefferson 10,497 ft
Three Sisters 10,358 ft
Mt. Bachelor 9,065 ft
Newberry Crater
Mt. McLoughlin 9,495 ft
Mt. Shasta 14,162 ft
Medicine Lake volcano
Lassen Peak 10,457 ft
CASCADE RANGE
BRITISH COLUMBIA
WASHINGTON
Vancouver
Georgia
Victoria
Strait of Juan de Fuca
Whidbey I.
Elliott Bay
Seattle
Puget Sound
Puyallup Valley
Orting
Olympic Mts.
Olympic Peninsula
Bainbridge Island
Olympia
Second Beach
Rialto Beach
Copalis Beach
North Beach Peninsula
Cannon Beach
Hood River
Sandy
Columbia
Portland
Mount Angel
Scotts Mil
Salem
Breitenth Hot Sprs
McKenzie Pass
Bend
Crater Lake
Klamath Falls
Upper Klamath Lake
OREGON
CALIFORNIA
Wilhelm
Waldport
Medford
PACIFIC OCEAN
Crescent City
Klamath
Oketo
Big Lagoon
Eureka
Cape Mendocino
Petrolia
Sugarloaf I.
Mendocino Fault

## When a Subduction Zone Rips

Straining against the locked zone on the subduction surface, the lower plate presses forward (A). It drags the toe of the upper plate with it, causing the coast to bulge upward. Finally, sufficient pressure builds to overcome the lock, and the lower plate moves in one great jerk (B). The toe of the upper plate and the seafloor rebound. Displaced water surges upward, then rolls seaward and landward as tsunamis (C). In addition, the bulge of land behind the toe falls (D). Trees that withstand the tsunamis die as their environment suddenly changes from coastal forest to salt marsh.



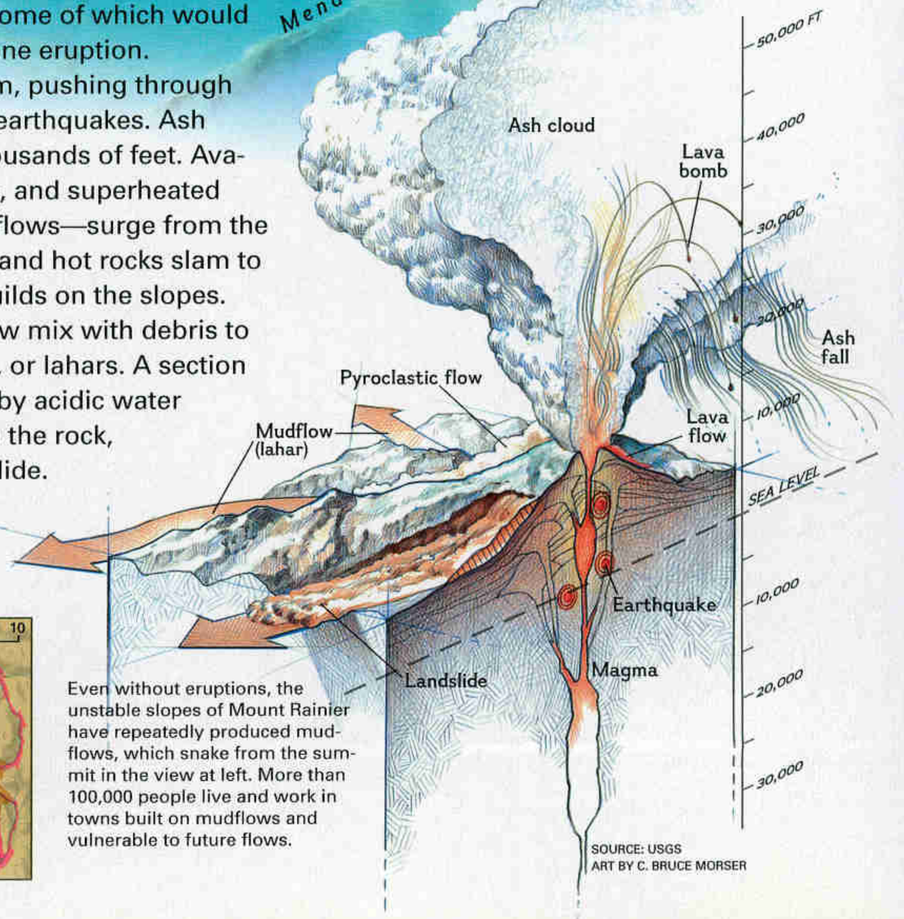

Scientists can monitor plate movement to within millimeters by using fixed antennas that receive information from global positioning satellites. As stress pushes land upward, the distance between the antennas shortens (1). When the lock snaps, the distance between them increases (2).

## When a Mountain Lets Go

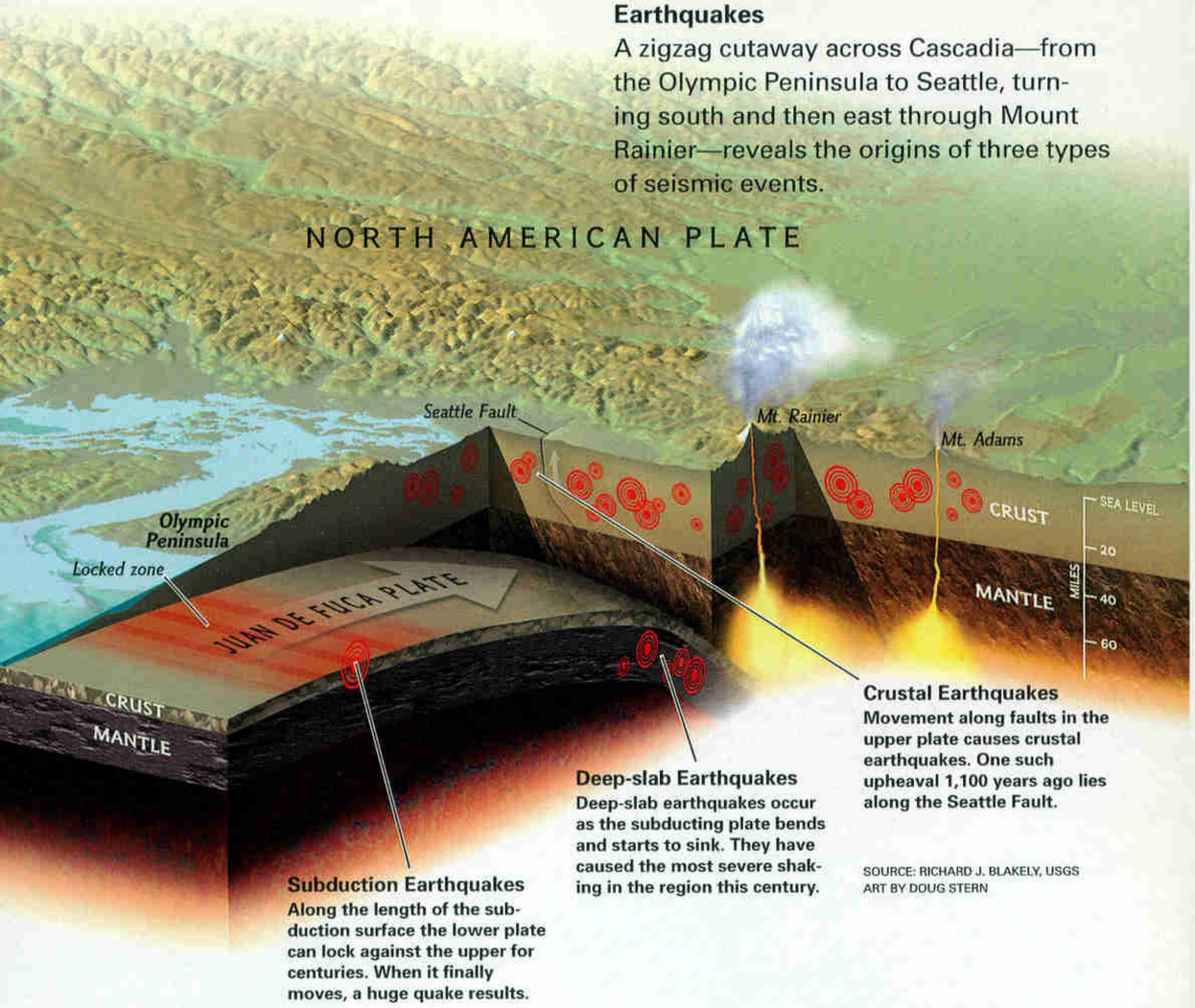
Rumbling to life, a volcano can set terrifying events into motion. Here, a model of Mount Rainier illustrates the possibilities in Cascadia—only some of which would likely occur in any one eruption.

Magma and steam, pushing through rocks, set off small earthquakes. Ash billows, often to thousands of feet. Avalanches of ash, rock, and superheated gases—pyroclastic flows—surge from the crater. Lava bombs and hot rocks slam to the ground. Lava builds on the slopes. Melting ice and snow mix with debris to form floods of mud, or lahars. A section of the slope, rotted by acidic water percolating through the rock, collapses in a landslide.


Even without eruptions, the unstable slopes of Mount Rainier have repeatedly produced mudflows, which snake from the summit in the view at left. More than 100,000 people live and work in towns built on mudflows and vulnerable to future flows.




SOURCE: USGS
ART BY C. BRUCE MORSER




**Earthquakes**
A zigzag cutaway across Cascadia—from the Olympic Peninsula to Seattle, turning south and then east through Mount Rainier—reveals the origins of three types of seismic events.

**Crustal Earthquakes**
Movement along faults in the upper plate causes crustal earthquakes. One such upheaval 1,100 years ago lies along the Seattle Fault.

**Deep-slab Earthquakes**
Deep-slab earthquakes occur as the subducting plate bends and starts to sink. They have caused the most severe shaking in the region this century.

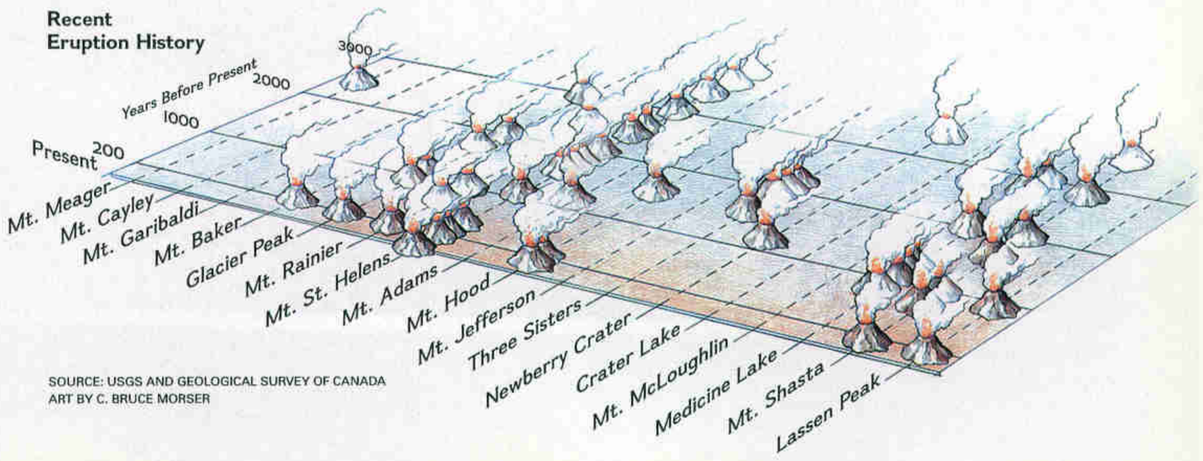
**Subduction Earthquakes**
Along the length of the subduction surface the lower plate can lock against the upper for centuries. When it finally moves, a huge quake results.

SOURCE: RICHARD J. BLAKELY, USGS
ART BY DOUG STERN

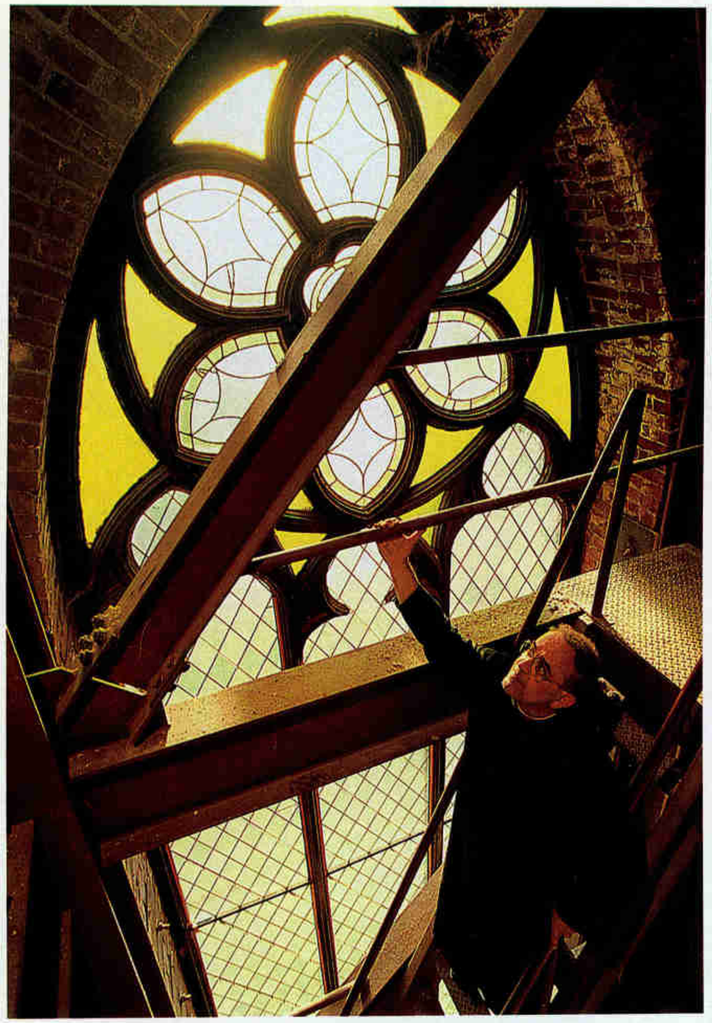
## UNSETTLING DETAILS

**Volcanoes**

Cascadia's soaring landmarks seem ageless, but all have arisen in only the past several hundred thousand years. "These are young volcanoes built on the remnants of older ones that are, themselves, built on volcanoes that are even older," says Ray Wells of USGS. "We can trace that history in the Cascades to about 40 million years, and it probably goes back further." Though eruptions occur erratically, they are inevitable in an active subduction zone. As the oceanic plate descends, increased temperature and pressure force its fluids upward, causing rocks in overlying layers to melt. Less dense than the continental crust, the melted rock, or magma, rises to the surface—often explosively.




SOURCE: USGS AND GEOLOGICAL SURVEY OF CANADA
ART BY C. BRUCE MORSER



Citizens should know to head uphill as soon as they feel a strong quake. Such guidelines may seem simple enough to implement, but even after the meeting ends, Waldport's leaders continue to debate the best ways to do so.

Farther north along the Oregon coast, the town of Cannon Beach has already developed a tsunami awareness program. At noon on a July day tourists fill downtown streets, eating ice-cream cones and meandering in and out of gift shops. Suddenly the air is filled by the sound of an angry cow mooing from six loudspeakers set up throughout the town. A voice explains that the bovine ruckus is simply a test of the town's tsunami warning system.

"Some people don't like the noise," says Al Aya, president of the Cannon Beach Fire District, which initiated the system in 1988. "But we've got nine miles of recreational beaches and thousands of visitors. Little kids play in the water. We can't have them swept away."

Residents might have less than half an hour to reach high ground, so powerful sirens will sound immediately after any earthquake is felt. But in many locations along Cascadia's coastline people could have trouble reaching safety in time. About 1,500 people, for instance, live on a low-lying sand spit across Humboldt Bay from Eureka, California. Only one bridge connects this spit with the mainland. That bridge almost certainly will fail during a subduction earthquake. Likewise, the residents of Washington's North Beach Peninsula, essentially a 25-mile-long sandbar, have only one way off. In the summer thousands of panicked tourists could be trapped.

THE POTENTIAL for Cascadia's earthquakes doesn't end with the subduction zone. "There are actually three forces duking it out in the Pacific Northwest," says Ray Wells, a tall, lanky plate-tectonics specialist at USGS. Wells, who heads a project to assess the hazards underlying the urban corridor of the Northwest coast, takes me on a field trip directly through harm's way.

"Subduction is certainly one important force," he says as we drive east out of Medford, a booming city in southern Oregon, toward the chain of volcanoes that forms the backbone of Cascadia. "But the entire region is also being butted from the south by a large chunk of northern California, including the Sierra Nevada."

That block of California, he explains, is being dragged northwest by the massive Pacific plate and is causing western Oregon to rotate out to sea around a pivot point near Portland. The push from the south is also jamming Oregon into Washington, causing crustal earthquakes and helping to lift the Olympic Mountains.

The third force putting pressure on Cascadia, says Wells, is the Basin and Range—the vast expanse of mountains and valleys that extends between the Cascade and Sierra ranges on the west side and the Rocky Mountains on the east. Geologic heating beneath the Basin and Range has forced that region to swell up

and push westward, eating into the Cascades from the east. To see the impact of the Basin and Range on Cascadia, we head for the town of Klamath Falls, which in September 1993 was surprised by a 5.9 magnitude earthquake, the largest to be felt in Oregon since 1872.

We drive through old volcanic rocks, created, as are all lavas in subduction zones, deep beneath the land's surface at a point where the rocks in the subducting plate grow warm enough to release the abundant water that had been bound up in their minerals. That water migrates upward, lowering the melting point of overlying rocks and turning them into magma. That magma, laden with gases under high pressure, works upward through zones of weaker rock. Eventually the magma breaks through to the surface, creating volcanoes.

As we climb into the western foothills of the Cascades we drive through a canyon that exposes the base of one of the earliest Cascade volcanoes. It is part of a now vanished range of giants that formed when subduction first began beneath Cascadia about 40 million years ago. Today the zone of melting beneath Cascadia has shifted east, so these basement rocks are all that's left of once lofty volcanoes. But one of the subduction zone's most recent offspring gleams in the distance like a snow-streaked pyramid sitting astride the current axis of volcanism.

"That's Mount McLoughlin," says Wells. "More than 9,000 feet high and almost a perfect cone."

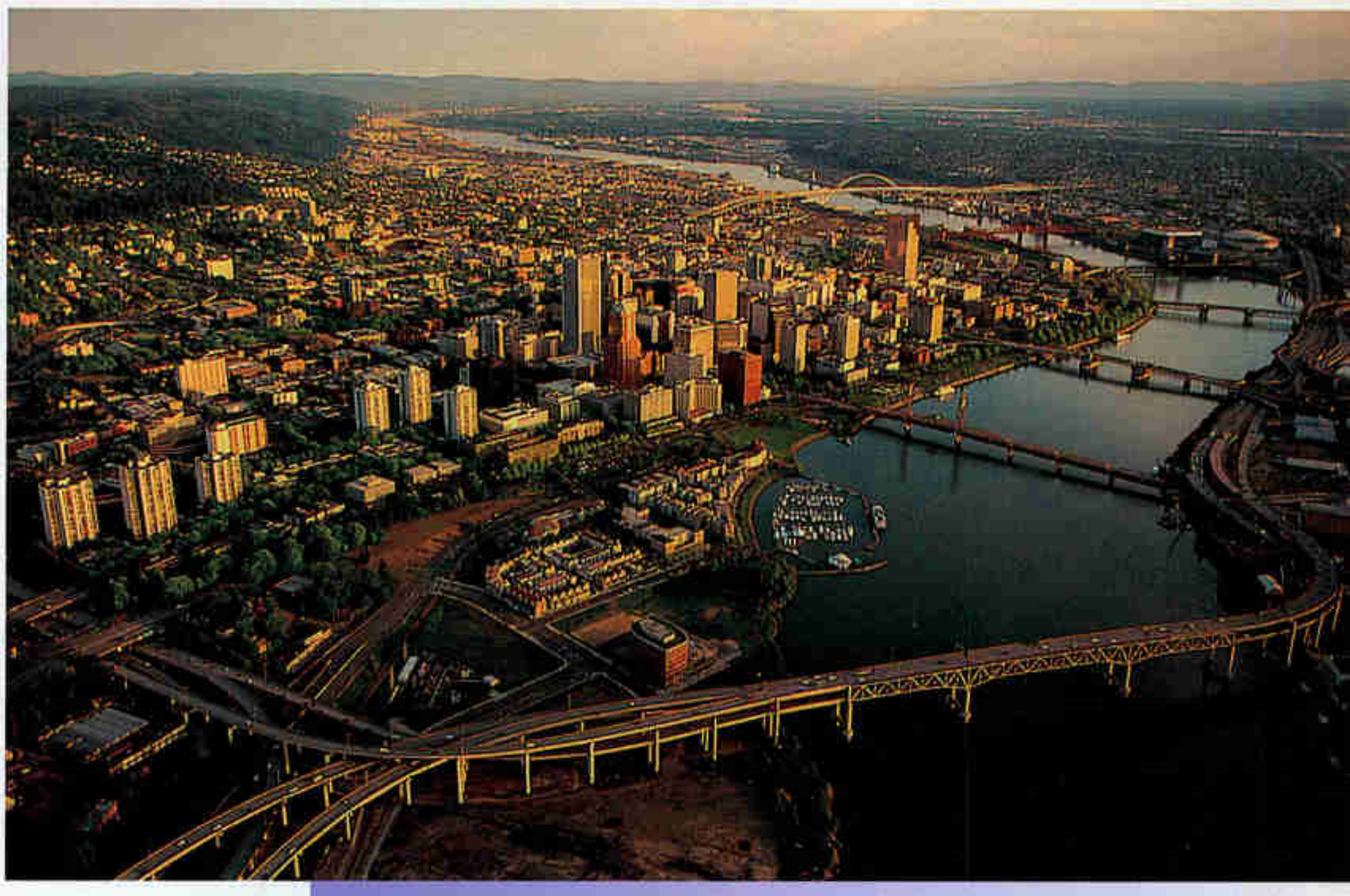
Soon Mount Shasta comes into view, some 75 miles to the south. It last erupted in 1786. To the north lie Crater Lake and hundreds of other volcanoes, large and small, aligned along a north-south arc. We descend into a valley largely filled by 20-mile-long Upper Klamath Lake. High cliffs on both sides of the lake mark faults along which the valley floor is dropping, creating a big hole.

"We have just entered the Basin and Range," says Wells. "Earth's crust here is stretching, cracking, and extending into Cascadia."

Downtown Klamath Falls remains scarred by that last crack, which pummeled the town with what Wells calls "a wake-up call for all Oregon." A chain-link fence surrounds the two-story county courthouse, its fractured walls now condemned. Vacant lots mark where buildings were torn down after being damaged too severely to repair. On the road north of town, flowers along a fence commemorate the spot where a driver was killed when the quake flung a boulder off a cliff onto his truck.

We drive north toward the city of Bend, then cut back west into the heart of the Cascades. We pass the jagged peaks of the Three Sisters, Mount Bachelor, and Three Fingered Jack. At McKenzie Pass we stand on a sea of black lava that erupted across 40 square miles about 1,500 years ago.

We descend into the flat agricultural Willamette Valley, famous for its fruits and vegetables. Like Klamath Falls, towns here were shaken in 1993 when a 5.6 temblor, known as the Scotts Mills earthquake, woke them on the morning of March 25.



**ON SHAKY GROUND**

Straddling faults, Portland, Oregon, has strengthened some buildings as well as the interstate highway bridge in the foreground to better withstand the force of future quakes. Thirty miles south in Mount Angel, Father Edmund Smith inspects steel beams that now brace the Church of St. Mary, damaged by the 1993 Scotts Mills temblor. "We only have two choices," says state geologist Don Hull. "Reduce the risk before the earthquakes, or pick up the pieces later."

MOUNT HOOD

Besides sheer beauty, Oregon's highest peak lures visitors with places to hike, camp, fish, and play. "Some of the more active folks ski in the morning and then drive to Hood River to windsurf that afternoon," says Bob Tilling, a USGS volcanologist monitoring the area.

"I thought it was a herd of elk going across my deck," recalls Larry Owings of the Molalla River School District, whose historic high school was condemned after the quake.

The Scotts Mills earthquake occurred along a shallow fault created as the upper crust of Cascadia was crunched from the south by California, a process that continues today. But no one had known exactly where the fault was—a situation that's disturbingly common in Cascadia.

**MOVING EVIDENCE**

"If the tide were high, water would be up to my waist," says USGS geologist Brian Atwater, who cuts a section from a dead western red cedar in a Washington salt marsh. Growth rings show that nearby trees died around the time of the great quake of 1700, when land fell and the ocean flooded coastal forests. A slip on the Seattle Fault 1,100 years ago lifted Bainbridge Island's former shoreline about the height of the rod held by Brian Sherrod, also from USGS.

"Out on the desert you can find faults easily," explains Silvio Pezzopane of USGS. "In Cascadia the surface is covered over by trees, glacial debris, or sediments. The faults are difficult to find, they erode, and only the largest events break the surface."

But faults can create small local variations in the magnetism of the crust, and by analyzing aerial magnetic surveys, USGS geologist Rick Blakely has been finding evidence of many subsurface faults in Oregon. Along with Pezzopane and Ray Wells, Blakely suspects that the same fault that created the Scotts Mills earthquake may connect with other faults closer to Portland. The longer the fault, the more powerful an earthquake it can produce. And a quake doesn't have to be that strong to devastate an urban area. The earthquake that rocked Kobe, Japan, in 1995 measured only 6.9. The Northridge quake in Los Angeles in 1994, which took a 20-billion-dollar toll, was a 6.7.

"We now think we've grossly underestimated the number of large crustal earthquakes that could hit the Puget Sound area," says Craig Weaver, a USGS seismologist working at the University of Washington.

Weaver and several colleagues meet me on Bainbridge Island, about seven miles across the sound from downtown Seattle, to show what a quake on one of those hidden faults can do. We walk onto the fairway of a country club along the shore. Seattle's skyline sparkles in the distance as we climb about 12 feet down a cliff onto a rocky beach. One of Weaver's colleagues, Brian Sherrod, points out holes halfway up the cliff that were drilled more than a thousand years ago by a marine mollusk called a rough piddock. He reaches up and plucks a clam shell out of the cliff.

"All these mollusks were living underwater," he says. "The ground here was uplifted 21 feet by an earthquake that probably measured about magnitude 7.5."

That uplift probably also generated a tsunami that swept across the sound, depositing layers of sand in marshes north of Seattle. Radiocarbon dates of marsh plants caught in those deposits indicate that the earthquake hit about 1,100 years ago. It struck along a seismic zone known as the Seattle Fault, which geologists hadn't even documented as active until about five years ago.

NATIONAL GEOGRAPHIC, MAY 1998

"We now know this entire Puget Sound region is riddled with hidden faults," says Sam Johnson, a USGS geologist.

I join Johnson on a refurbished tugboat, the *Robert Gray,* which is towing seismic surveying equipment over the sound, trying to locate some of those faults. The faults are particularly difficult to find here; a layer of glacial debris 3,000 feet deep in places mantles the bottom of the sound.

To penetrate that layer, the boat is towing an air gun and another noise-making device to fire sound waves into the muddy bottom. Every ten seconds the air gun pulses a sonic shot downward, inaudible to us but creating a burp of white water behind the boat. Microphones arrayed along a separate line pick up the echo of the shot as it bounces back off rocks and sediments below.

Different geologic structures reflect sound waves in different ways. Computers onboard the *Robert Gray* compile the data and turn out cross-sectional images. Known as seismic profiles, the images let Johnson and his colleagues identify the buried faults and evidence of their recent activity.

Today the crew is studying a 50-mile-long fault that runs offshore from Whidbey Island. Geologists recently realized that a massive earthquake occurred along that fault about 100,000 years ago. Johnson's team hopes to get more information on how often earthquakes recur there.

They have already mapped three strands of the Seattle Fault zone. They determined that those strands are cut by another previously unknown north-south fault zone in the center of the sound. They have also determined that strain builds up along that fault at the rate of about four-hundredths of an inch a year. In Seattle the impact of a major break on one of those faults would be profound.

"Downtown would be challenged," says John Hooper, a structural engineer in Seattle. The city's newer high-rises would probably not collapse, he says. But Seattle, like Portland, has many older structures built of brick walls without bracing or support, and many of them

might be too damaged to be functional. And Seattle's entire waterfront lies atop fill. In earthquakes such loose soils often liquefy, behaving like quicksand. If that happens along the waterfront, the harborside could splay out into the sound. A major freeway known as the Viaduct would probably collapse. And a repeat of the tsunami that struck the area 1,100 years ago would take many casualties on the waterfront, including ferryboat passengers.

Though such earthquake hazards have been widely publicized in the Seattle area, many residents view the problem with detached bemusement. A series of small quakes rocked the region during the summer of 1997, swaying skyscrapers and getting everyone's attention.

"We all just kind of looked at each other," reports a local friend, John Treat. "People still think earthquakes are California's problem."

Across the Canadian border Vancouver and other cities in British Columbia are also facing the unfamiliar. The possibility of subduction quakes has sent earthquake insurance rates soaring in some locations. Emergency planners are struggling to alert residents to the hazard.

"We've had our heads in the sand," says Allan Galambos, an engineer involved with the seismic upgrading of bridges along British Columbia's south coast. Galambos has helped pioneer a disaster-response program, which includes designating a network of routes for emergency vehicles only. Bridges are particularly vital lifelines for Vancouver, whose central business district sits on a peninsula. Yet Galambos says that only two of the ten major bridges he oversees would be secure in a big quake. Liquefaction would threaten most. But the cost of adequately strengthening those bridges is prohibitive. "We'd have to spend 25 million dollars a year for the next ten years," he says. "Our budget this year is only $150,000."

Because earthquakes would cost so much and affect so many people, they pose by far the greatest hazard to Cascadia. But the big volcanoes of the region are also of concern. On May 18, 1980, the eruption of Mount St. Helens killed 57 people and humbled volcanologists by exceeding their worst-case scenarios for what the mountain could do.* To help explain what he and his colleagues learned the day St. Helens erupted, Ed Wolfe of USGS's Cascades Volcano Observatory takes me by helicopter into the mountain's steaming crater.

"Where we are landing was inside the mountain the day before it exploded," says Wolfe, as we prepare to set down on gray rubble. "Nearly 4,000 feet of rock would have risen above our heads."

Although it's officially in repose, the mountain still seems alive. Rockfalls continually crash down the 2,000-foot-high crater walls, sending huge boulders embedded in billowing dust clouds racing toward us.

*See "Eruption of Mount St. Helens," by Rowe Findley, in the January 1981 issue.

**DÉJÀ VU**

Hummocks pop up like prairie dog mounds across 175 square miles near Mount Shasta (above). Geologists puzzled over their origin until the Mount St. Helens eruption, whose huge landslide created similar terrain (above right). Subsequent study revealed that about 300,000 years ago

"This is only a moderately hazardous place to be now," says Wolfe. "Since 1480 there have been four major eruptions here. The one in 1480 was about five times bigger than the one on May 18, 1980."

On a timescale of centuries St. Helens is now the most active of all Cascade volcanoes. Whereas Mount Adams, a huge Cascade volcano to the east, was born about half a million years ago, St. Helens is only 40,000 years old. But it has blown itself apart so often that few rocks in the mountain today are more than 4,000 years old. St. Helens may be so active because it lies in a seismic zone between two faults where the earth is stretching apart. That stretching might be creating passageways for the magma below.

One of the most important lessons of the 1980 eruption, says Wolfe, is that volcanoes can collapse. They can be weakened structurally by injection of magma or actually rotted from the inside by corrosive hydrothermal fluids that convert hard rocks to clay. In the case of St. Helens, two months of magmatic intrusion had forced the north flank outward hundreds of feet, fracturing its rock and making it too steep to be stable. When a magnitude 5 earthquake struck the mountain that day in May, the bulging north flank and old summit collapsed in a massive landslide traveling at the rate of about 80 miles an hour and spreading a blanket of debris as thick as 600 feet for more than 17 miles. If that weren't enough, the collapse exposed and depressurized the magma that had been steadily rising within the volcano.

"It was like popping a champagne cork," explains Wolfe. "Within seconds a cloud of hot gas, rock debris, and magma blasted out of the opening that had been created by the landslide at more than 200 miles an hour. It overtook the landslide. Then for nine hours the volcano blew ash into a column 65,000 feet high, spreading it as far as Montana."

a landslide 20 times the size of the one at St. Helens destroyed an ancestral version of Shasta. "It was one of those 'Ah ha!' kinds of things," says USGS volcanologist Robert Christiansen, who helped figure it out. "Once you know the right answer, it's obvious. But no one had thought to imagine something of that magnitude."

THE LANDSLIDE on Mount St. Helens and resulting mudflow have forced volcanologists to reexamine other Cascade volcanoes. They haven't had to look far.

About 50 miles north of St. Helens rises 14,410-foot-high Mount Rainier, the tallest of the Cascade volcanoes. Tom Sisson, a young geologist at USGS, has spent much of the past five summers climbing Rainier, collecting rock samples from often precipitous slopes in order to determine the history of the 500,000-year-old mountain.

Unlike St. Helens, Rainier does not usually erupt explosively, Sisson explains. Its style is to pump out lava flows that gradually build the mountain. He takes me on a steep climb to a meadow on the western flank of the mountain. The debris-covered Puyallup Glacier cuts through the valley below us, while ice-mantled cliffs known as the Sunset Amphitheater tower above. Built from layers of old lava flows, those cliffs appear discolored even from this distance.

"They've been corroded by acidic fluids

# MOUNT BAKER

Taking his work to extremes, USGS geochemist Robert Symonds collects magma-heated steam in icy Sherman Crater. Mostly water from rain and snow, the steam also holds gases such as carbon dioxide. A change in the mix of components often signals a shift in volcanic activity.

circulating through this part of the volcano's plumbing system," Sisson says. He climbs several hundred feet down a scree-covered slope to fetch a rotted, orange-size rock. He smacks it against a boulder, breaking it open.

"This used to be hard rock," he says, giving me half. It crumbles in my hand.

About 500 years ago a huge chunk of rotted lava crumbled from the cliffs of the Sunset Amphitheater. The debris avalanche, known as the Electron Mudflow, melted immense amounts of Rainier's ice, mixed with it, and then roared down the Puyallup Valley, ripping through forests and burying the valley floor in a blanket of mud 20 feet deep.

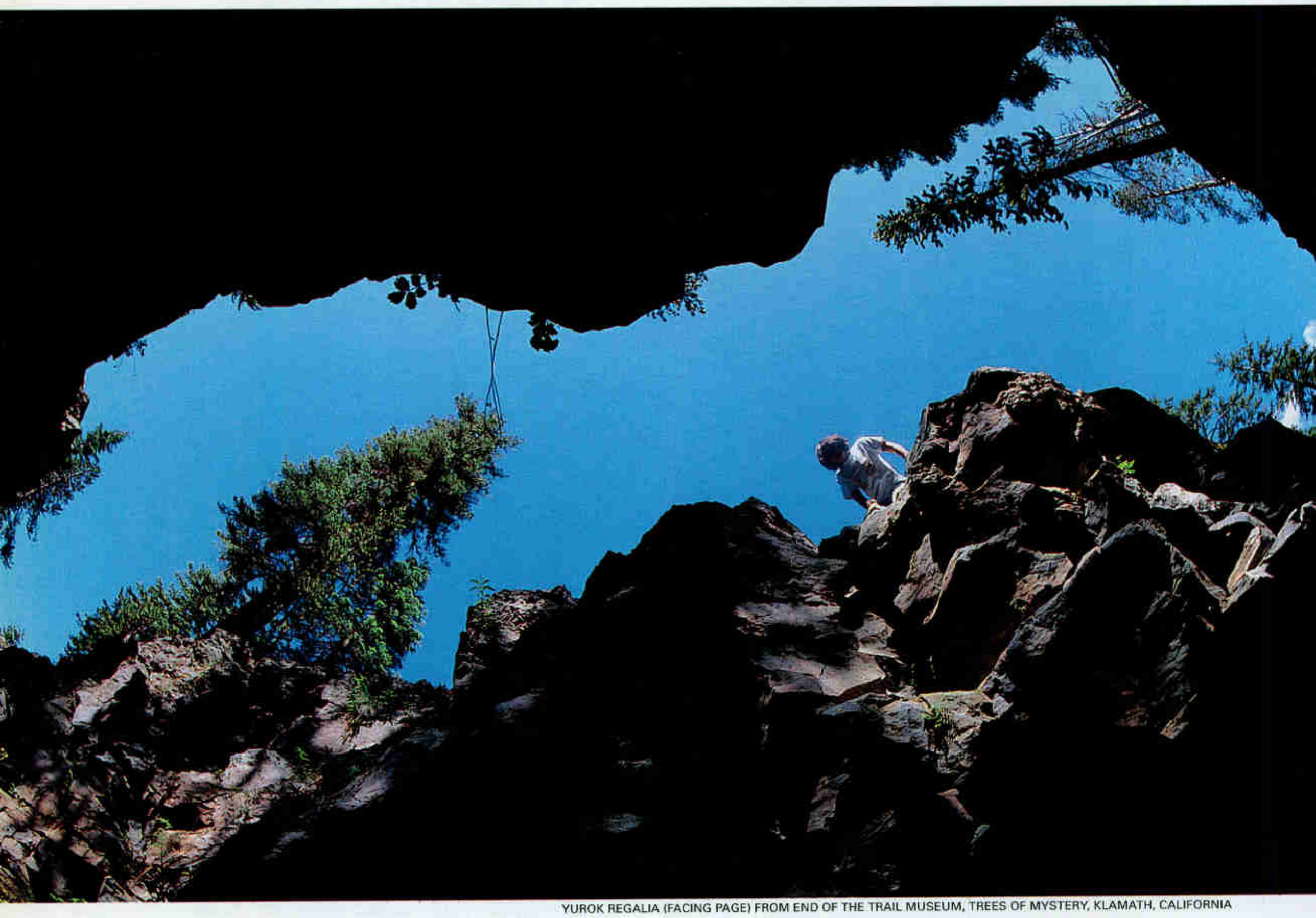
Geologists now know that mudflows—or lahars—like the Electron are not rare. "There've been at least 7 and perhaps 12 in the past 5,600 years," says Kevin Scott, a USGS geologist who has been documenting past flows.

The 5,600-year date he cites is an apocalyptic marker. That's when the entire northeast side of the mountain slid off in what's known as the Osceola Mudflow. Traveling a hundred miles an hour, it slowed to the pace of a galloping horse by the time it reached Puget Sound.

"A repeat would go through the big industrial corridor south of Seattle into Elliott Bay, where the Port of Seattle is located," says Scott.

Far smaller mudflows would devastate the fast-growing communities closer to the mountain. The town of Orting, for instance, is built on top of the 500-year-old Electron Mudflow.

"It would have come through as a crashing, ripping wave," says Pat Pringle, a geologist with the state's Department of Natural Resources. "You couldn't have outrun it."



YUROK REGALIA (FACING PAGE) FROM END OF THE TRAIL MUSEUM, TREES OF MYSTERY, KLAMATH, CALIFORNIA

The town has installed evacuation sirens, but since Rainier's mudflows can occur without warning, one could be almost on top of the town before an alarm was sounded. This uncertainty creates anxiety. When I pass through the entrance of Mount Rainier National Park with a USGS team, the ranger on duty, Lindsay Carlson, notices the Survey emblem on our van. "Is something happening?" she asks nervously.

But most residents regard their odds of

being covered by a mudslide as remote. Kevin Scott, however, calculates the odds in any one year to be about one in 500, more likely than having your house catch fire.

AFTER RAINIER, the volcanic fires most hazardous to Cascadia residents probably burn beneath Mount Shasta, far to the south in northern California. "It's a very scary volcano," says Charles Bacon, a USGS volcanologist.

But people living within eyesight of Shasta regard this 14,162-foot-high volcano mostly with reverence. Visible from as far away as a hundred miles, its white flanks seem to anchor northern California to the Earth.

"It's one of the power centers of the planet," says a friend, Jim Berenholtz. Berenholtz, an artist and musician in San Francisco, is among the many pilgrims who come to Shasta. Some believe fervently that the mountain is inhabited by refugees from a lost continent, aliens from space, angels, and other spirits.

Native Americans pray to the mountain but do so from afar. "It's beyond sacred," says Mary Carpelan of the Shasta Nation. "It's the home of Waka, the Creator, when he comes to visit. Our people never go on the mountain."

"It's the source of our power," agrees another Native American, Jack Thom. Thom tells me that he has seen the mountain open up and bright light stream out of it. Scientists believe that Shasta has indeed opened up in the past. And the light that streamed out would have been incandescently hot, accompanying a collapse of the entire mountain about 300,000 years ago.

"That collapse was 20 times bigger than at Mount St. Helens," says Bob Christiansen, the volcanologist who was in charge of the USGS monitoring team the morning St. Helens blew. After seeing the chunks of debris that spread across the landscape in lumpy hummocks, he realized that similarly shaped hills on the north side of Mount Shasta had been created by the same phenomenon.

"They are actually pieces of an earlier Mount Shasta that must have rotted and collapsed," he says. The sweeping scale of the landslide was too big for geologists to have comprehended before Mount St. Helens.

Since that collapse Shasta has rebuilt itself, creating four distinct cones. The youngest and highest of them, called Hotlum, is as young and as large in itself as Mount St. Helens.

"Shasta has been the most active volcano in the Cascades after St. Helens," Christiansen says. "Over the past 6,000 years it has erupted about every 200 to 300 years, the last time in the 1700s. A big eruption here could threaten the I-5, the major transportation route on the West Coast, along with major utility corridors."

The other Cascade volcanoes, from Lassen

**WORLDS OF INSIGHT**

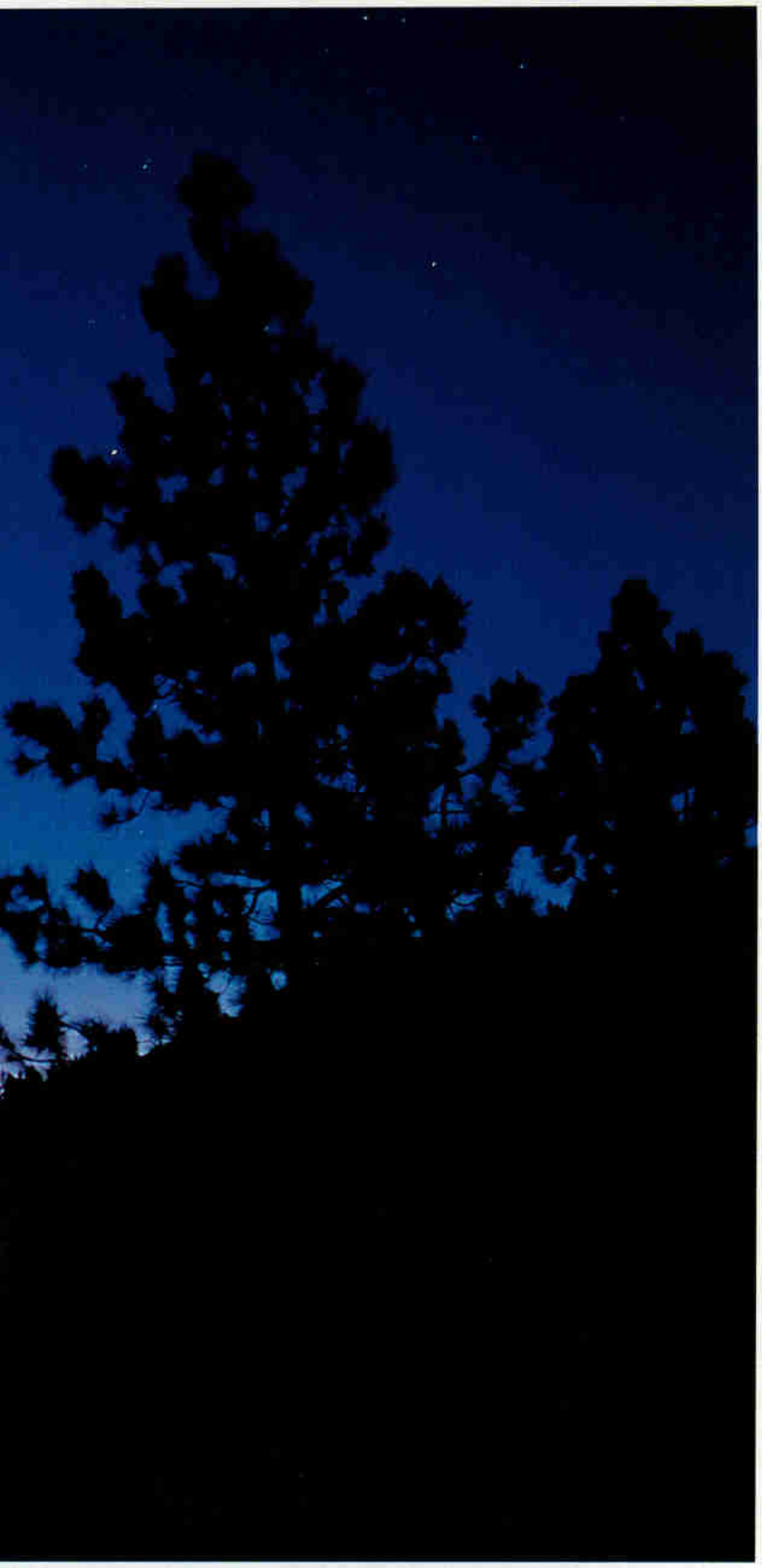
Near the caldera rim of Medicine Lake volcano, USGS geologist Julie Donnelly-Nolan surveys a crack that opened 1,100 years ago. Scientists have only begun to study such events; the native Yurok believe the Creator taught them about Earth's movements at the beginning of time. Every two years Walt McCovey, Jr., and other elders don regalia and perform a ceremony to balance the Earth. "We're not doing this just for our own people," he says. "It's for everyone."

**RECURRING WONDERS**

Blazing briefly over Mount Shasta last year, comet Hale-Bopp should return to our skies in about 2,400 years. By then eruptions will likely have reshaped the volcano's silhouette several times, judging from the geologic record, while humans scramble to safety and then return. "This is a very pleasant place to live, but to enjoy the benefits you have to put up with some of the occasional burps and outbursts," says Bob Tilling. "The challenge for scientists is to provide warnings in enough time so that no one gets hurt."

Peak in northern California to Mount Meager in British Columbia, pose lesser hazards. Most are too remote to affect many people. But Mount Hood, which is Portland's playground, could send avalanches of hot gases and volcanic debris down its world-famous ski runs. Parts of its upper flanks have rotted, and a partial collapse could trigger mudslides down the Sandy River, taking out the pipelines that supply much of the city's water.

And most of the major volcanoes could go into the rare kind of spasm that created Crater Lake in Oregon about 7,700 years ago. At that



time a volcano called Mount Mazama, about 50 miles north of Klamath Falls, stood about 12,000 feet high. Then, in the largest explosive eruption known to have occurred in the Cascades, it beheaded itself, creating the lake-filled caldera that is one of Oregon's most popular scenic attractions.

"It threw its guts out on the landscape all at once," says Charles Bacon, the USGS expert who spent four field seasons climbing the harrowing slopes of the caldera. Although an eruption of that scale probably will not occur in the near future, the area remains hazardous. "An explosion in shallow water within the caldera could send a surge of volcanic debris hot and fiery enough to toast you alive and cover you with mud if you were within a couple of miles of the crater rim," says Bacon.

ON MY LAST DAY in Cascadia I seek relief from the endless stream of potential catastrophes I have been hearing about. I ask the Canadian geophysicist Garry Rogers and his colleague Mike Schmidt to take me to the end of Cascadia, on northern Vancouver Island along a remote fault zone near Nootka Island. We fly low in a seaplane over rocky beaches where impenetrable forests come right to the water's edge. We pass isolated tribal villages and clusters of brightly dressed sea kayakers. We land on the island in Friendly Cove, at a tiny settlement that includes a couple of houses, a lighthouse, and an old church.

We meet Ray Williams, a Mowachaht and the only permanent resident on Nootka. Most of his people have moved to a nearby town, but Williams decided to stay on this misty cove. "Living here," he says, "tells the white people this is our land."

Williams introduces me to the Mowachaht chief, Ambrose Maquinna, and other friends who are visiting for a few days. The talk turns to legends, and Rogers asks if they have stories that might indicate the occurrence of ancient earthquakes. The chief, a large man with a full face, glasses, and grizzled whiskers, nods. His friend, Thomas Dick, answers: "My grandmother spoke of a great flood. The water came up and suddenly there was no land, nothing to tie the canoes to. People had to leave. They scattered everywhere. Some went to California, others to Russia."

The fires beneath Cascadia, it seems, have been affecting the people of this land throughout history. And as unlikely as all those worst-case scenarios may be in my lifetime, they are eventually going to happen. Again and again. At least until the embers beneath Cascadia burn out. And anyone who has to walk those hot coals should remember the rules of etiquette my instructor Ariel taught me: Take a deep breath, and always respect the fire. □

To read more from author Rick Gore about fire walking, go to www.nationalgeographic.com and click on the 2000 icon.

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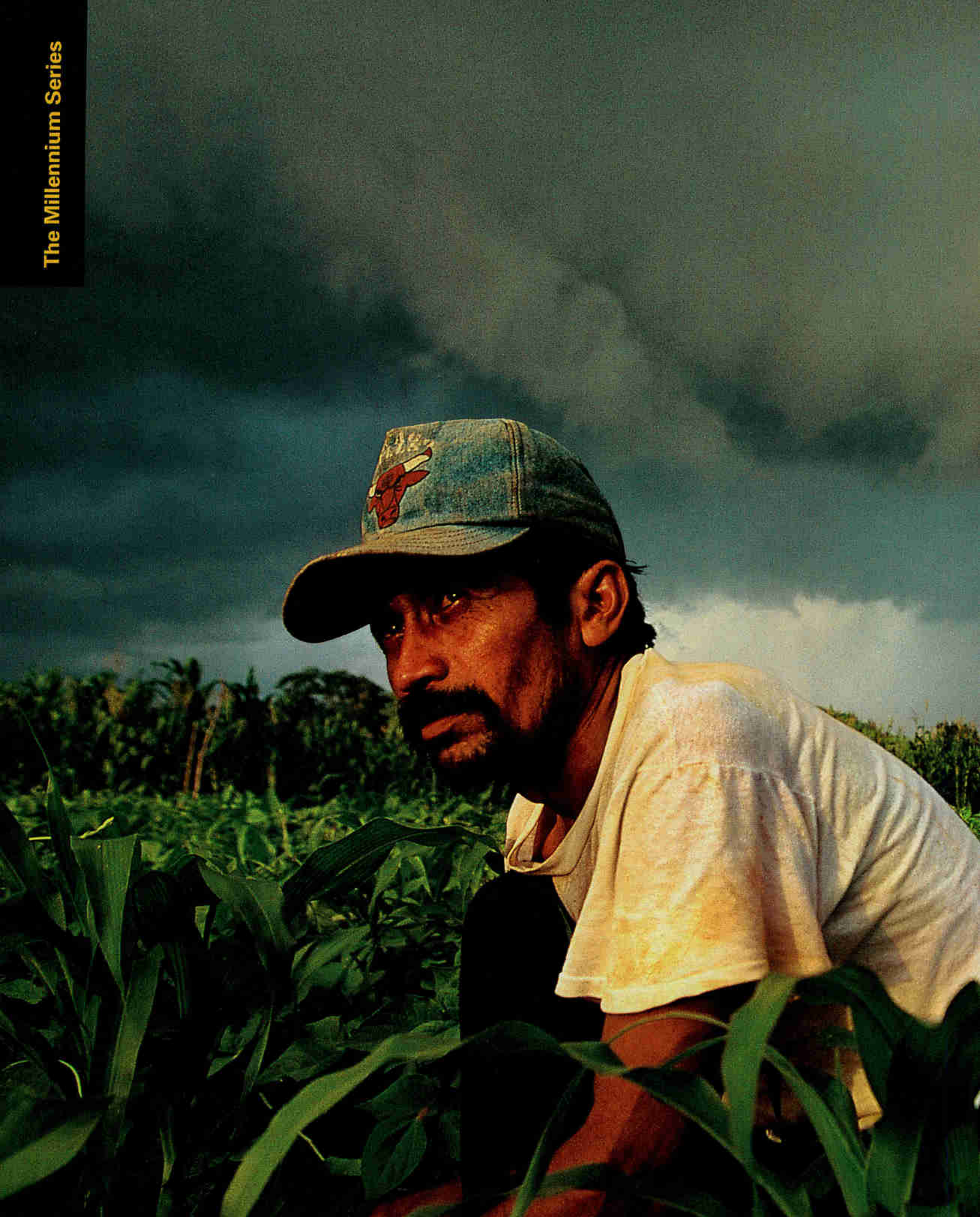


# Unlocking the Climate Puzzle

The world is getting warmer, and humans are partly responsible, experts say. But many pieces of information do not yet fit, and others remain elusive.

The rains bearing down on farmer Pastor Trejo Acosta's bean and corn fields in Yucatán, Mexico, are a welcome change from last year, when drought killed his crops. Next year, who knows? New studies are helping scientists see trends that make long-term climate projections less of a guessing game.

# Are fossil fuels digging up trouble?

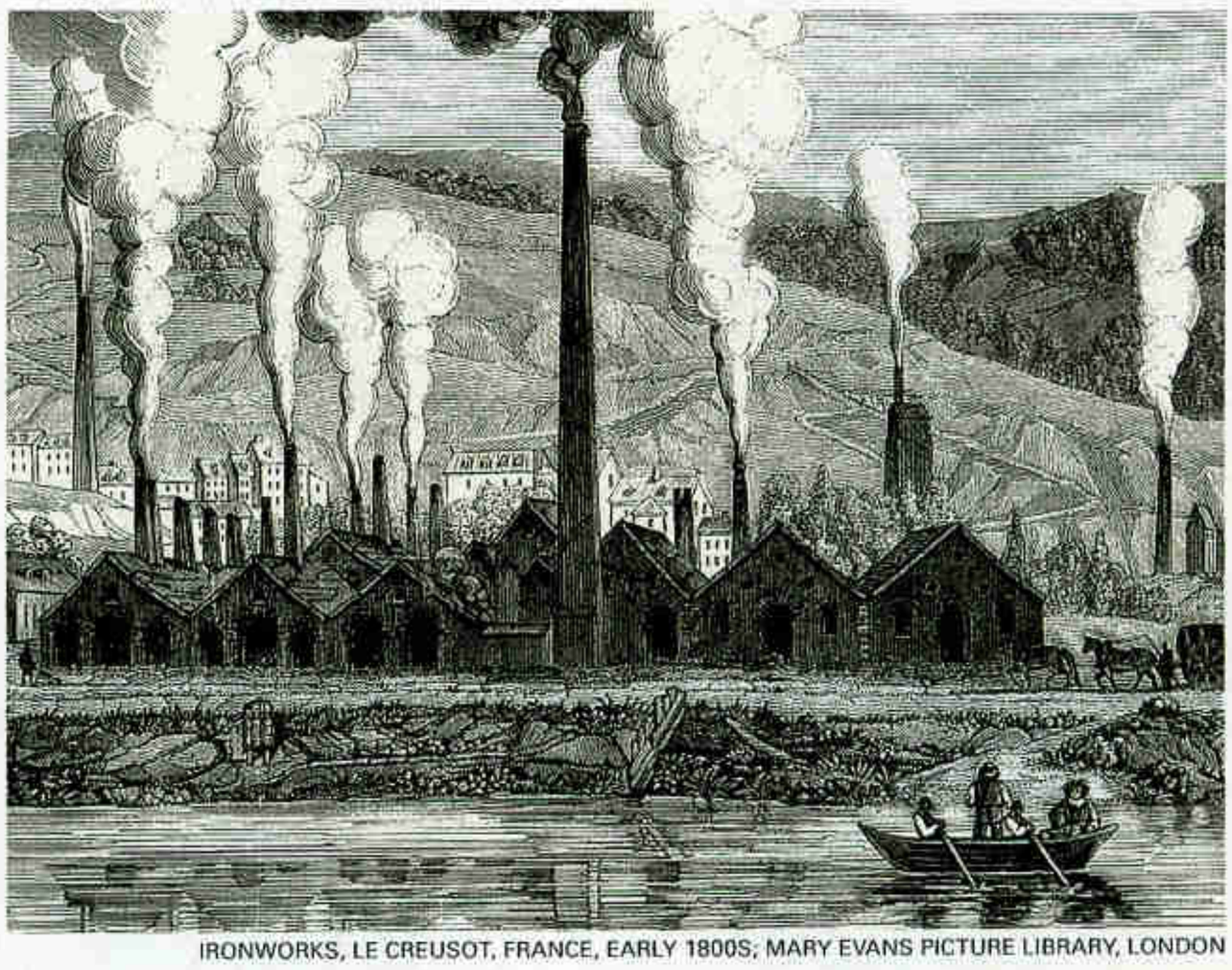
Turning the planet inside out, miners 260 feet down in eastern India dig coal that will release carbon dioxide ($CO_2$) into the atmosphere when burned. As emerging nations join their industrialized neighbors in burning more fossil fuels, the amount of $CO_2$ in the air is expected to double in the next century. Most experts, while acknowledging the awesome complexity of Earth's climate system, believe higher $CO_2$ levels carry a real threat of raising global temperatures and bringing about significant climate change.

Then the rains came no more.

Blowing sand from a dry lake bed clings to Tinalbaraka walet Mohamed's eight-month-old daughter, Isha, as mother and children sleep on a sun-baked afternoon in Mali. Just 25 years ago lakes dotted the homeland of these nomadic Tuareg people. The rains stopped in the 1970s, but population growth and overgrazing did not. If computer models are right, areas like this could get even drier as Earth heats up. "We used to fish, grow crops, have animals, and prosper," says Tuareg leader Mohamed Ali. "Now it is a country of thirst."

BY CURT SUPLEE PHOTOGRAPHS BY JOANNA B. PINNEO

# Untangling the science of climate



IRONWORKS, LE CREUSOT, FRANCE, EARLY 1800S; MARY EVANS PICTURE LIBRARY, LONDON

LIFE HAS PROSPERED on this planet for nearly four billion years. In that time climate has fluctuated drastically, from ice ages lasting tens of thousands of years to epochs of steamy heat. With each change, sundry species have benefited and flourished. Others adapted, faltered, or died.

Now, many experts believe, humans are imperiling their own ecological niche with the threat of global warming. The vaporous by-products of civilization, in the form of greenhouse gases such as carbon dioxide ($CO_2$), have trapped enough heat in the atmosphere to raise Earth's average surface air temperature a half degree Celsius (one degree Fahrenheit) during this century. If the trend continues, it could alter climate patterns worldwide—thawing glaciers, boosting sea level, scorching plains into deserts, and shifting vegetation zones.

Or it might not. Global climate depends on combinations of factors interacting in subtle and complex ways that we do not yet fully understand. It is possible that the warming observed during this century may have resulted from natural variations, even though the increase has been much more rapid than what the planet has witnessed over the past hundred centuries. Moreover, the supercomputer simulations used to project future conditions may not be accurate.

Nonetheless, in 1995, after years of intense study, the Intergovernmental Panel on Climate Change (IPCC), sponsored by the United Nations, concluded tentatively that "the balance of evidence suggests that there is a discernible human influence on global climate." The

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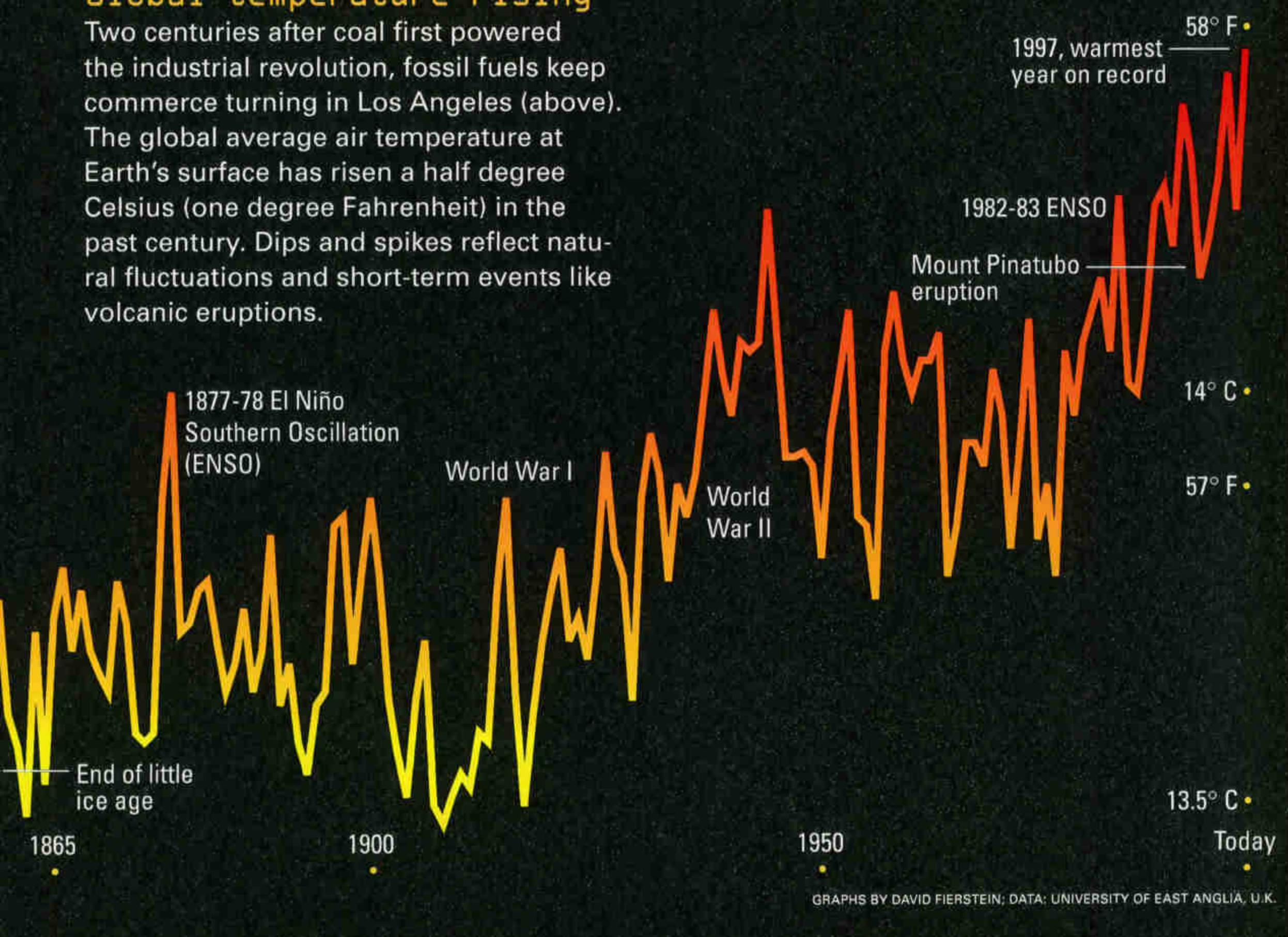
CURT SUPLEE, a *Washington Post* science writer, covered robots for the July 1997 GEOGRAPHIC. JOANNA PINNEO, a frequent contributor, most recently photographed Nunavut in the September 1997 issue. She lives in Colorado.

The U.S. is the major contributor of greenhouse gases.

## Global temperature rising

Two centuries after coal first powered the industrial revolution, fossil fuels keep commerce turning in Los Angeles (above). The global average air temperature at Earth's surface has risen a half degree Celsius (one degree Fahrenheit) in the past century. Dips and spikes reflect natural fluctuations and short-term events like volcanic eruptions.




GRAPHS BY DAVID FIERSTEIN; DATA: UNIVERSITY OF EAST ANGLIA, U.K.

amount of that influence, the group noted, is unknown because of "uncertainties in key factors," including the degree to which clouds and the oceans affect the rate of temperature change. It may take a decade or more of additional research to resolve those uncertainties.

Meanwhile, much *is* known. And although the specific consequences of human activity remain ambiguous, our ability to alter the atmosphere is incontestable.

## The Greenhouse Effect

The air we breathe keeps us alive in more ways than one. Without our atmosphere, average global temperature would be about minus 18°C (minus 0.4°F) instead of the present 15°C (59°F). All the incoming sunlight, with energy equivalent to about three 100-watt lightbulbs per square yard, would strike Earth's surface, causing it to emit infrared waves like a giant radiator. That heat would simply travel unimpeded back out into the void.

Because of the atmosphere, however, only a fraction of that heat makes it directly back into space. The rest is trapped in the lower air layers, which contain a number of gases—water vapor, $CO_2$, methane, and others—that absorb the outgoing infrared radiation. As those gases heat up, some of their warmth radiates back down to the surface. The entire process is called the greenhouse effect, and most of it is caused by the predominant greenhouse gas, water vapor.

With increased heating, more water evaporates from oceans, lakes, and soils. Because a warmer atmosphere can hold more water vapor, this creates a powerful feedback loop: The hotter it gets, the higher the water vapor content of the air, and thus the greater the greenhouse warming.

Human beings have little direct control over the volume of water in the atmosphere. But we produce other greenhouse gases that intensify the effect. The IPCC estimates that rising $CO_2$ emissions, mostly from burning fossil fuels, account for about 60 percent of the warming observed since 1850. Carbon dioxide concentration has been increasing about 0.3 percent a year, and it is now about 30 percent higher than it was before the industrial revolution. If current rates continue, it will rise to at least twice preindustrial levels by about 2060—and by the end of the century could be four times as high. That is particularly worrisome because $CO_2$ has a lifetime of more than a hundred years in the atmosphere, compared with eight days for water vapor.

Methane, the principal ingredient of natural gas, has caused an estimated 15 percent of the warming in modern times. Generated by bacteria in rice fields, decomposing garbage, cattle ranching, and fossil fuel production, methane persists in the atmosphere for nearly a decade and is now about 2.5 times as prevalent as it was in the 18th century. Other major greenhouse gases include nitrous oxide—produced by both agriculture and industry—and various solvents and refrigerants like chlorofluorocarbons, or CFCs, which are now banned by international treaty because of their damaging effect on Earth's protective ozone layer.

The relentless accumulation of greenhouse gases has led the IPCC to project that in the next hundred years global average temperatures will rise by 1 to 3.5 degrees C. That may not seem like much. Yet the "little ice age," an anomalous cold snap that peaked from 1570 to 1730 and forced European farmers to abandon their fields, was caused by a change of only half a degree C.

But how credible are current projections? The computer models used to project greenhouse effects far into the future are still being improved to accommodate a rapidly growing font of knowledge. And it is remarkably difficult to detect a definitive "signature" of human activity in the world's widely fluctuating climate record.

## Models and Uncertainty

To project future climate patterns, scientists use computer simulations of the interactions among land, air, water, ice, and sunlight. These general circulation models, or GCMs, consist of equations representing the known laws of atmospheric physics and ocean circulation. For each section of the planet, they calculate the effect of such factors as air temperature, Earth's rotation, and surface friction on sea level, rainfall, and other climatic conditions. A perfect model, if given enough information about conditions on Earth several hundred years ago,

could provide an exact description of today's climate. Only very recently have models been developed that are capable of realistically depicting the present global climate without a lot of tinkering—adjustments often called "fudge factors."

In part this is because only the most powerful computers are fast enough to handle the job, and in part because some aspects of climate change are still mysterious. Even avid proponents caution that GCMs are not yet trustworthy for predicting detailed effects in individual regions: Models divide the world's surface into grids that are typically about 200 miles on a side, but ocean eddies, storms, and cloud activity take place on far smaller scales. The modelers therefore have to compensate with approximations.

According to Kevin Trenberth, chief climate analyst at the National Center for Atmospheric Research in Boulder, Colorado, all GCMs project global warming, but they can provide only a range of projected temperature change. The warming could be one degree C over the next century, or it could be as much as three times greater than that. "Used properly, models are useful tools," Trenberth says, "but they cannot solve the problem."

## A Case of Missing Carbon

With oceans and clouds, uncertainty is a formidable problem. Oceans serve as a vast "sink" for carbon dioxide, but precisely how they do so is poorly understood. We do know this: Human activity releases approximately 7 billion metric tons of carbon (in the form of $CO_2$) into the atmosphere every year, adding to the 750 billion tons that is already there. Yet only about half our emissions—3 billion tons—remains in the air. The rest is taken up by terrestrial and marine plants, buried in ocean sediments, absorbed in seawater, or otherwise sequestered. Of that "missing" amount of carbon, the oceans apparently remove at least 2 billion tons from the atmosphere each year.

This raises a number of compelling but so far unanswered questions: How, exactly, does seawater interact with the air above it to remove $CO_2$? How much more carbon can the seas hold, and what level of global warming would it take to alter their capacity? And how much has the oceans' ability to soak up and store heat delayed climate change?

The role of clouds and airborne suspended particles called aerosols is no easier to factor into models. Clouds shade Earth's surface, promoting cooling, but depending on their altitude, density, and other conditions, they can also trap outgoing heat, promoting warming. Aerosols are equally tricky. Some encourage water vapor in the air to condense into tiny droplets. The resulting clouds are dense and shiny, shading the surface for weeks. Similarly, smoke particles block sunlight until they precipitate out of the air. The combined effect can be sizable: The volcanic eruption of Mount Pinatubo in 1991 in the Philippines blew a colossal amount of sulfates into the stratosphere, causing a worldwide drop in temperature that lasted two years.

Thus, ironically, our own pollution, mainly from combustion of sulfur-bearing coal and oil, may temporarily have spared us some effects of global warming. The National Oceanic and Atmospheric Administration (NOAA) estimates that during the 20th century, aerosols reduced the amount of warming that would otherwise have occurred by perhaps 20 percent. In general, temperatures rose until the 1940s but then dropped significantly until 1970, when they began rising again to set records. Aerosol effects may help explain the odd mid-century cooling.

If $CO_2$ emission increases are to blame for global warming, skeptics say, then temperatures should have risen appreciably during the postwar economic boom, when fossil fuels were burned in escalating quantity. Jerry Mahlman, director of NOAA's Geophysical Fluid Dynamics Laboratory at Princeton, however, has calculated that the surge in coal and oil use quickly increased the amount of sulfates aloft, prompting the cooling. After 1970 the longer term effect of $CO_2$ and methane overwhelmed the short-lived aerosols, accounting for the temperature rise since then.

An enhanced greenhouse effect may not necessarily be catastrophic. Indeed, it might be good news for some farmers. High concentrations of $CO_2$ can have a fertilizing effect on plants, which is why some commercial

greenhouses use an artificial indoor atmosphere containing $CO_2$ at about three times the level outside. Because plants use photosynthesis to turn $CO_2$ into living tissue, more vegetation also might mean more $CO_2$ scavenged from the atmosphere, perhaps slowing global warming.

Furthermore, higher temperatures might be most welcome where they are most likely to occur. Since 1900 the greatest warming has been observed between 40 degrees and 70 degrees north latitude—including Europe, Russia, and the northern half of the U.S.—where much of the world's industrial greenhouse gas emissions originate. Most of the warming has taken place at night—presumably because increased cloud cover shades the land by day and traps outgoing heat at night. The growing season in the northern U.S. has lengthened by about a week.

## As the World Warms

Warming of the magnitude anticipated by the IPCC could also prompt widespread calamity. For one thing, it would put a lot more water vapor into the air (about 6 percent more for every one degree C temperature increase), causing more rainfall worldwide and probably more intense weather generally.

Although the frequency of rain or snowfall may increase slightly, the most probable effect is that the average amount of precipitation in any given event will be greater, says Thomas Karl, a climate analyst at NOAA. In areas already prone to flooding, erosion, or both that may be a dire prognosis. It is also likely that increased precipitation would be extremely uneven, leaving regions such as the American Midwest drier in the summertime and making parts of Mexico and Africa even more arid than they are now.

In addition, Karl says, heat waves may become more serious if the land has less chance to cool overnight. An increase of 3 degrees C (5.4 degrees F) in the average July temperature for Chicago would raise the probability of killer heat waves (highs above 120°F) from one in twenty years to one in four.

Such grim visions appear increasingly plausible. There is virtually unanimous agreement that the global average surface air temperature has risen half a degree C since the late 1800s and that 13 of the warmest years of the 20th century have cropped up since 1980. By some measures, 1997 was the hottest. In sum, that would seem compelling evidence that people have contributed to global warming.

Yet the warming could be part of the natural roller coaster of average global air temperatures, which have varied by as much as 6 degrees C during the past 150,000 years. Climate fluctuates over thousands of years owing to periodic changes in the sun's energy output and in Earth's orbit and tilt, both of which influence the amount and intensity of sunlight reaching the surface. Proof of these climate shifts comes from variations in the composition of ice extracted in cores from the depths of ancient glaciers in Greenland and Antarctica and from differences among marine organisms in sediment cores taken from the seafloor.

It is possible that around 1860, when scientists first began keeping dependable temperature records, the planet was still recovering from the little ice age. The present warming might be a continuation of that rebound, and enhanced greenhouse warming may be superimposed on, and camouflaged by, that trend.

For many scientists, the critical issues are magnitude and speed of climate change. While a number of temperature shifts have occurred since the end of the last glacial ice age, some 10,000 years ago, the 20th-century warming of 0.5 degree C is unusually large, abrupt, and widespread.

"If climate keeps changing at the very rapid rate we think it will," says Thomas J. Crowley, an oceanographer at Texas A&M University in College Station, "the magnitude of future greenhouse warming will be large even on a geological scale."

## Anticipating the Future

How urgent is the need for immediate action of the sort contemplated at the 1997 climate change conference in Kyoto, Japan, in which the industrialized nations agreed in principle to cut their emissions of greenhouse gases? No question is more hotly debated among scientists and policymakers alike. Some argue that hasty measures are pointless: Any appreciable alterations in climate, they say,

Oceans play an important part in regulating climate.

Ocean currents carry heat around the globe and in turn are influenced by atmospheric conditions. Will progressive warming disrupt the cold-water habitats of fish like these sockeye salmon off British Columbia? For fisheries worldwide, that remains a billion-dollar question.

are likely to be gradual enough that we will be able to adapt. And even if all greenhouse gas emissions stopped tomorrow, the planet almost certainly would continue to warm for several decades because of the gases' long atmospheric lifetime.

On the other hand, there is evidence that some kinds of events could change climate radically in the span of decades or even years. Perhaps the most feared is an abrupt collapse in the huge Atlantic "conveyor belt" system that brings warm water north from the Equator, keeping Europe several degrees warmer than it would otherwise be. Evaporation of this incoming flow leaves the belt with a higher salt content than the rest of the North Atlantic, which is fed by substantial freshwater runoff from continental watersheds. The belt cools and becomes denser as it approaches Greenland, where it sinks. It then travels far below the surface in a south-moving return flow.

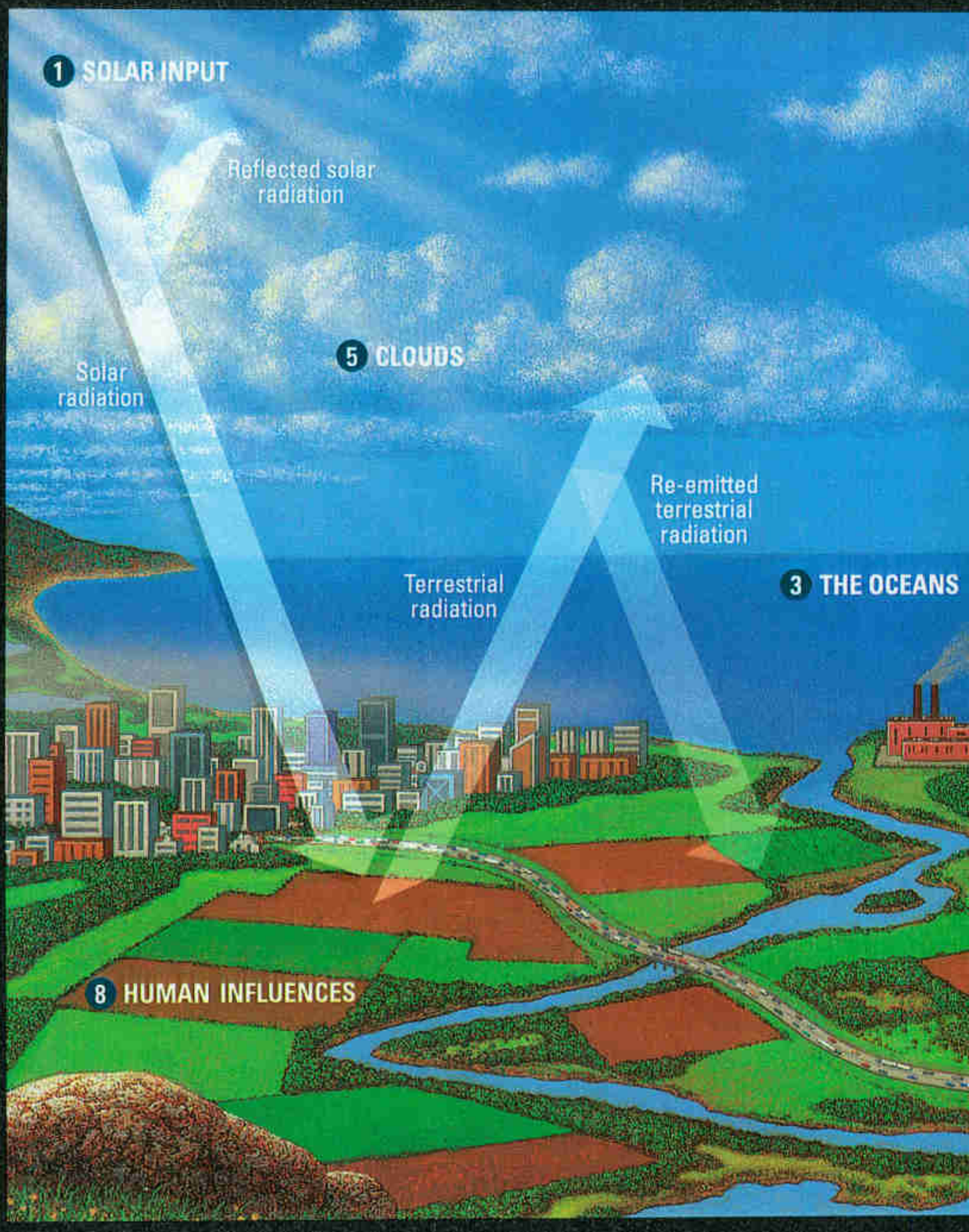
But what if human-induced global warming altered the delicate temperature difference between the flows and at the same time caused increased rainfall over the oceans, diluting the salinity of the northward flow? The whole Atlantic conveyor belt could simply shut down, as ocean-sediment evidence suggests it has several times in the past. The effect would be locally disastrous. By one estimate, Ireland would have about the same temperature as present-day Spitsbergen, which is hundreds of miles above the Arctic Circle. Much of northern Europe would be largely uninhabitable.

No one knows for certain whether such things will happen. Beyond that the specific human effect on climate change will remain hauntingly indefinite until our knowledge increases and the models improve.

"The next ten years will tell," Tim Barnett, a climatologist at the Scripps Institution of Oceanography in La Jolla, California, suggested recently. "We're going to have to wait that long to really see."

# What drives climate change?

Weather is what happens outside your home this morning. Climate is what you can expect to happen outside during your 30-year mortgage. Over time small changes can make a big difference. Driven by tremendous flows of heat over the surface of the planet, Earth's climate system is influenced by innumerable interacting variables.




## 1. Solar Input

Having traveled 93 million miles, solar energy hits the upper atmosphere at about the intensity of three 100-watt bulbs per square yard—one-third of which is reflected back into space. The rest of the energy warms Earth and fuels its weather engine.

## 2. The Atmosphere

A delicate balance of gases gives Earth an average temperature of 15°C (59°F). Greenhouse gases—water vapor, $CO_2$, methane, nitrous oxide, and others—absorb heat energy, then re-radiate a portion of it back to the surface.

## 3. The Oceans

Covering 70 percent of Earth's surface, oceans are the chief source of water vapor in the air. Oceans store heat efficiently and transport it thousands of miles. When warm water collects in one place, evaporation and cloud buildup may increase. Marine organisms consume huge amounts of $CO_2$.

## 4. The Water Cycle

Higher air temperatures can mean increased water evaporation and the melting of sea and land ice. Although water vapor is the most potent greenhouse gas, evaporation also leads to cloud formation, which can have a cooling effect.

## 5. Clouds

The role of clouds is poorly understood, but they are known to both cool Earth by reflecting solar energy and warm Earth by trapping heat being radiated up from the surface.

## 6. Ice and Snow

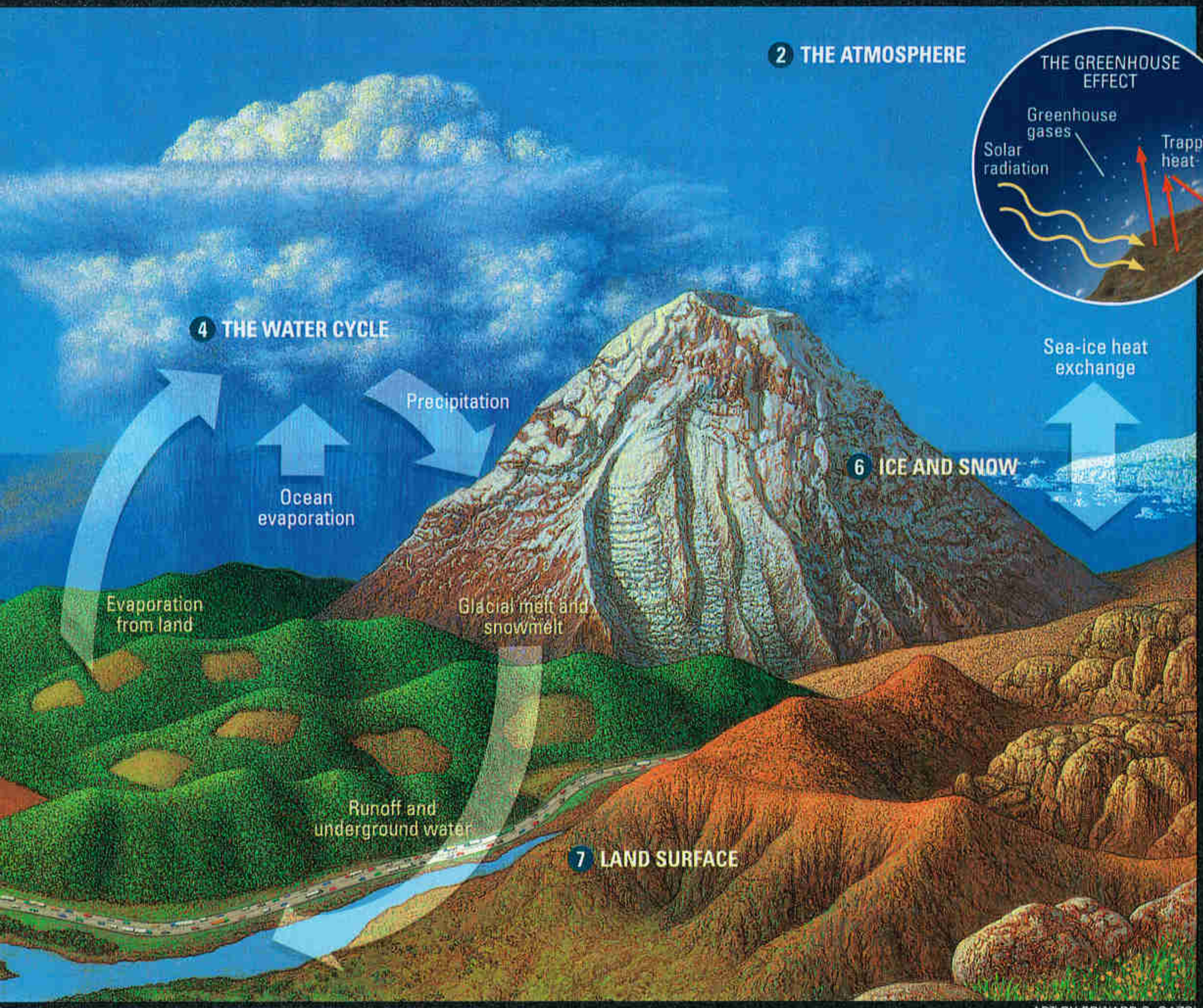
Bright white expanses of ice and snow reflect sunlight back into space, cooling the planet. Melting sea ice draws heat from the ocean. In the Northern Hemisphere snow cover has decreased about 10 percent in the past 21 years, but no significant melting of the Antarctic ice sheet has been detected.

## 7. Land Surface

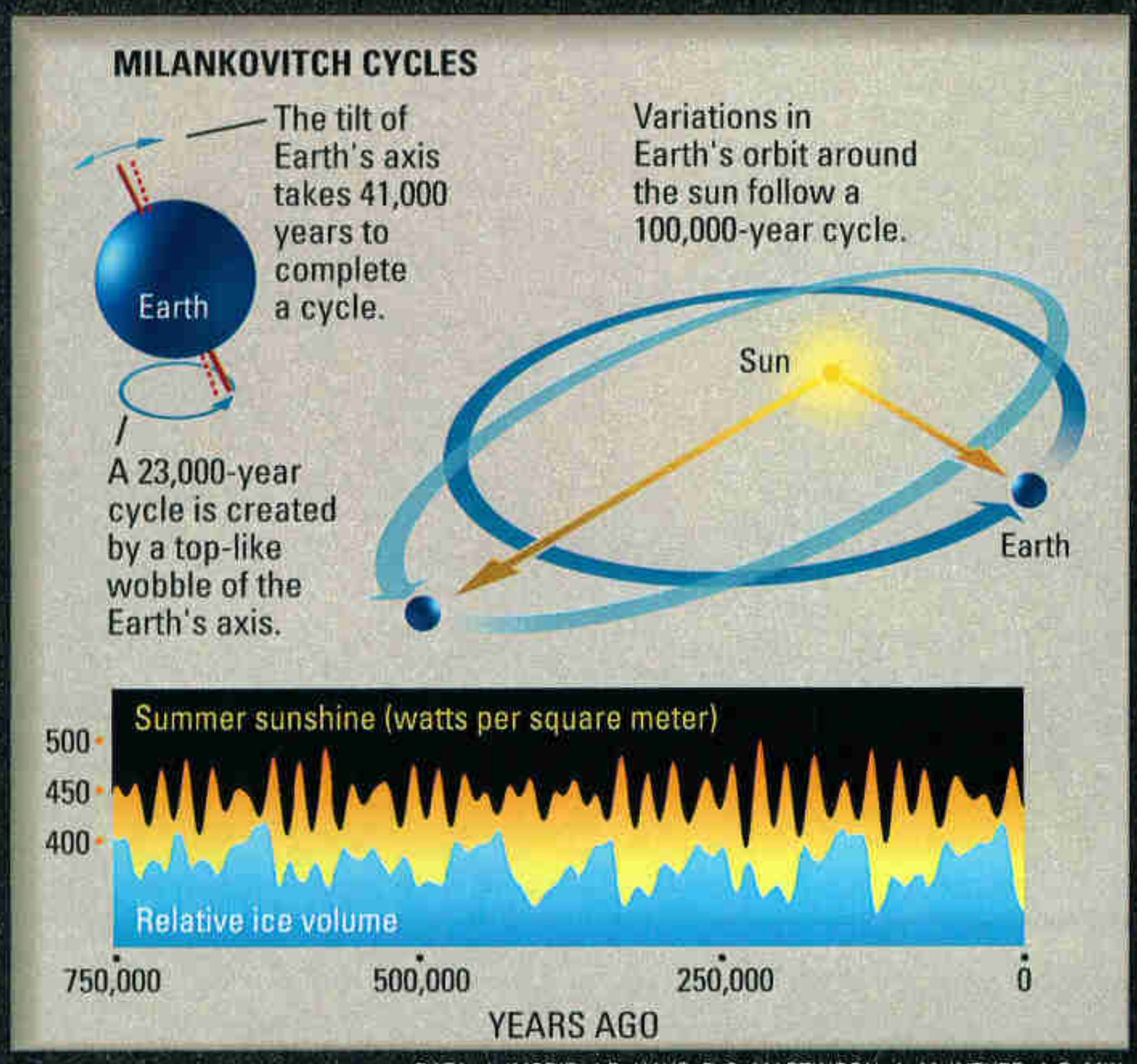
When solar energy penetrates the land surface it is converted into heat, most of which radiates upward quickly. Still, topography and land use can have major effects on climate. Mountain ranges can block clouds, creating dry "shadows" downwind. Sloping land allows more water runoff, leaving the land and air drier. A tropical forest will soak up $CO_2$, but once cleared for cattle ranching, the same land becomes a source of methane.

## 8. Human Influences

Adding to the mix of greenhouse gases naturally present in the atmosphere, human activities magnify warming effects. Fuel combustion is the chief cause of rising $CO_2$ concentrations. Ranching, rice farming, and landfills have raised methane levels. Aerosols, such as smoke and sulfates from industry, reflect sunlight and have temporary, localized cooling effects.




ART BY EDWARD S. GAZSI




DATA: J. IMBRIE, J.D. HAYS, D.G. MARTINSON, A. McINTYRE, A.C. MIX, J.J. MORLEY, N.G. PISIAS, W.L. PRELL, AND N.J. SHACKLETON

## MILANKOVITCH CYCLES

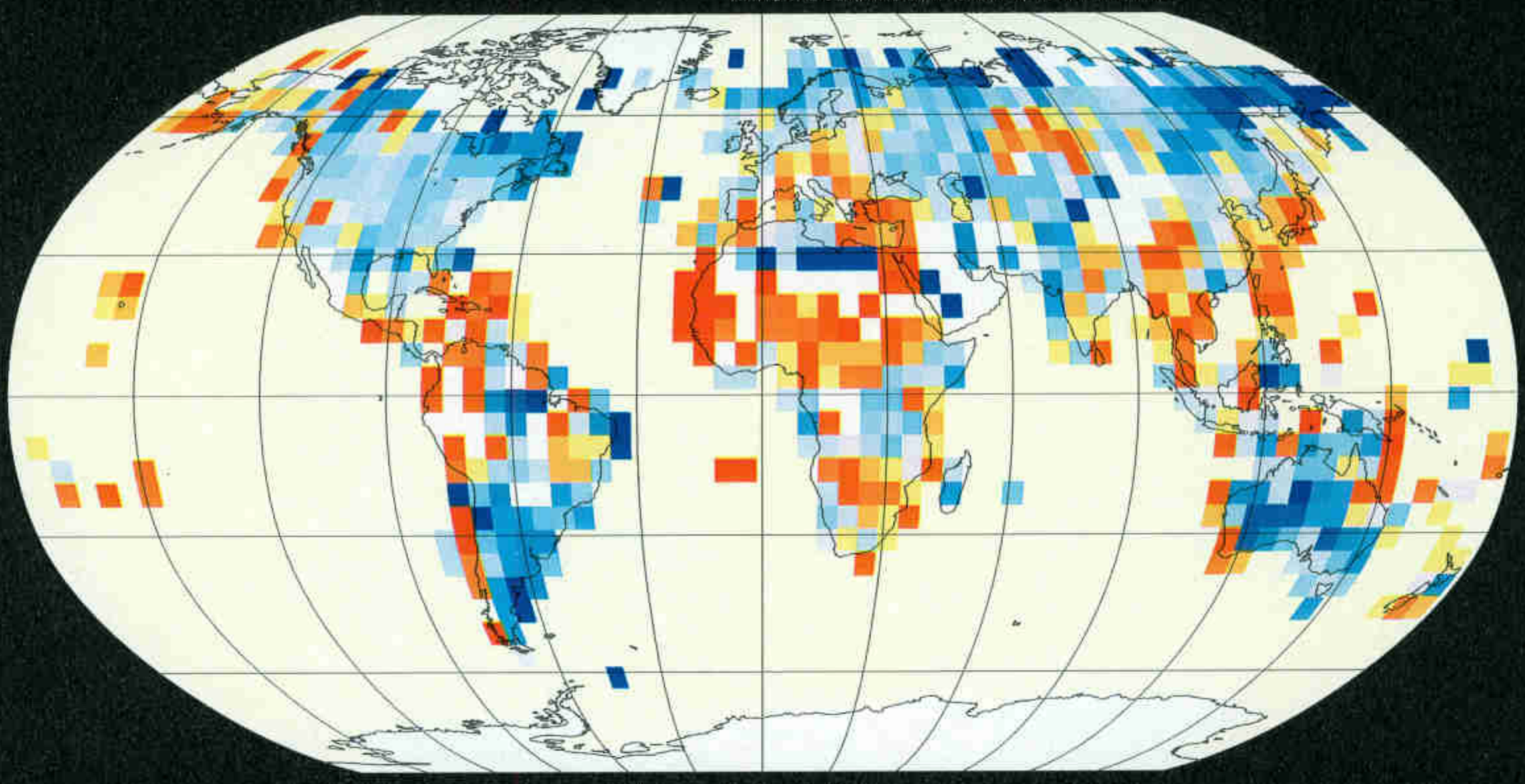
Like a wobbling top, the spinning Earth does not keep a constant position in relation to the sun. In the 1930s Serbian mathematician Milutin Milankovitch declared that three basic variations in Earth's movement affect global climate: A 100,000-year cycle of the planet's orbit, a 41,000-year cycle in the tilt of Earth's axis, and a 23,000-year cycle in the wobble of the axis. According to these cycles we should be in the midst of a long period of cooling. The effects of these cycles can be seen in Earth's ice sheets (graph, left), which grow when the intensity of sunshine decreases, allowing snow cover to last through the melting season and accumulate over time.

# The wet get wetter...

GLENN HARTONG (ABOVE) AND MICHAEL KEATING, BOTH *CINCINNATI ENQUIRER*

Relentless rains in March of last year pushed the Ohio River over its banks (above) and forced Roberta Minervini and her children to flee their New Richmond home, aided by firefighter Rick Mattingly. The same rains caused the Licking River, at 24 feet above flood stage, to reach for the rooftops of Falmouth, Kentucky (right). The flooding killed 23 people and destroyed some 400 million dollars' worth of property. Such rainfall is likely to become more intense, if not more frequent, in the future, say many experts. Warm air can hold more moisture than cool air, and with the global air temperature expected to rise between 1 and 3.5 degrees C (1.8 and 6.3 degrees F) over the next century, scientists predict more precipitation worldwide. Already there is more water in Earth's atmosphere than there was 25 years ago. Where will the new rains fall? All the experts can say for sure is that the distribution will be highly uneven; areas prone to flooding and erosion should prepare for more of the same.

NATIONAL CLIMATIC DATA CENTER, ASHEVILLE, N.C.



# And the dry get drier

"I haven't seen a drought like this in 69 years," says Bill Buchman, whose corn crop dried up under a rainless Maryland sun last August. Stalks that should have stood seven feet tall didn't reach his waist. So devastated was the state's corn crop that dairy farmer Lou Hobson (above, at right) couldn't feed his stock. He was forced to sell all his cows at auction. While farmers have always had to endure droughts and floods, recent trends are sobering. Compiling data on precipitation worldwide, scientists discovered that in this century some dry regions became even more arid, while many wet areas saw greater precipitation (map, left). Blue areas have increased rainfall, orange areas decreased rainfall. Regions with insufficient data are blank. "Might as well go to Las Vegas and gamble your money," says Hobson, "as to be a small farmer these days."

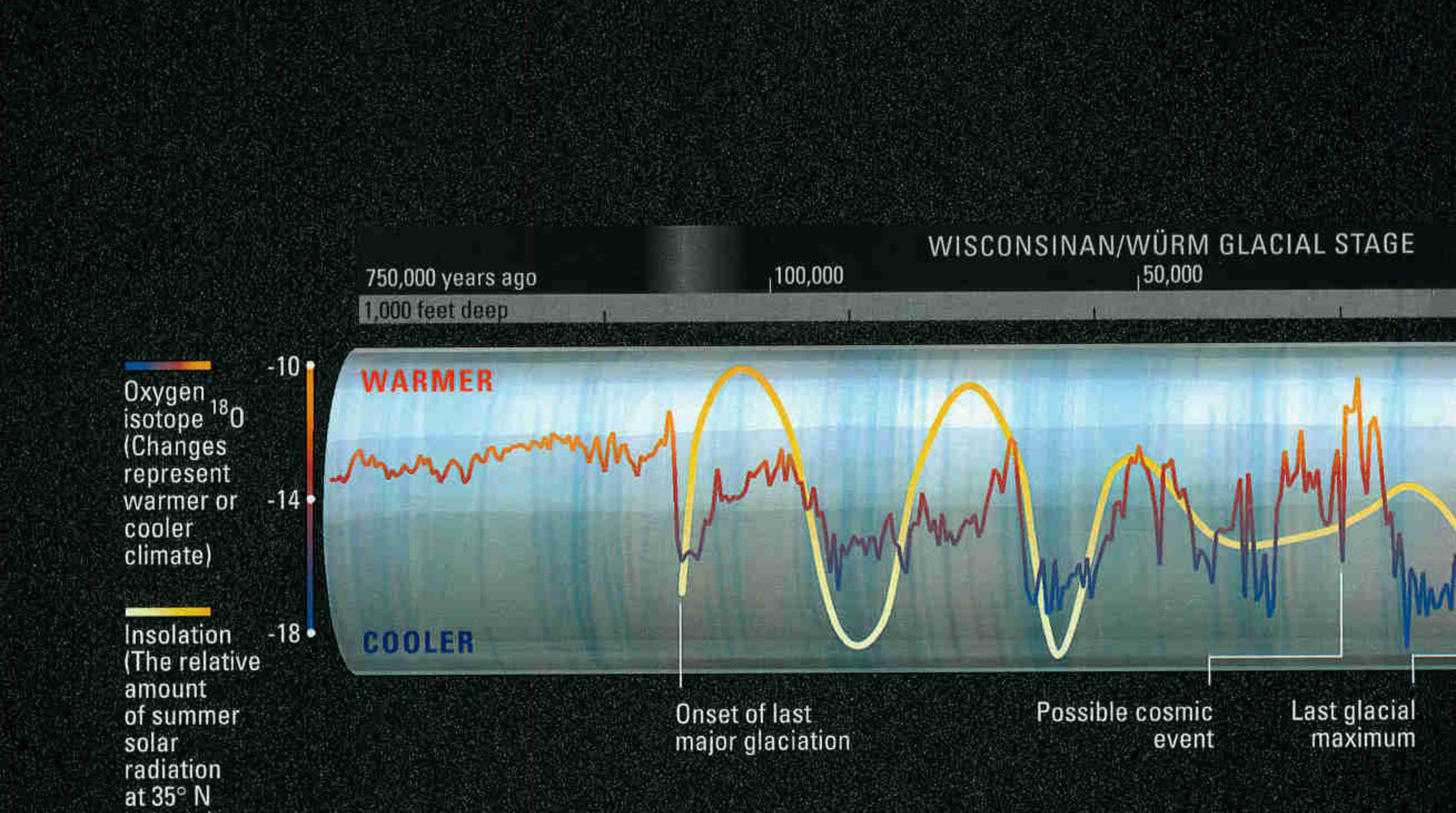
## Shifting ranges may reflect climate change.

Sensitive to temperature change, some butterfly species have been dying out in the southern reaches of their habitats and establishing new colonies farther north. These shifts may be in response to global warming, according to biologist Camille Parmesan of the University of California at Santa Barbara. Working in the Pyrenees mountains of Spain, her team found that while no species had moved south, nine, including this Apollo species, had shifted north. She has seen similar patterns in California butterflies.

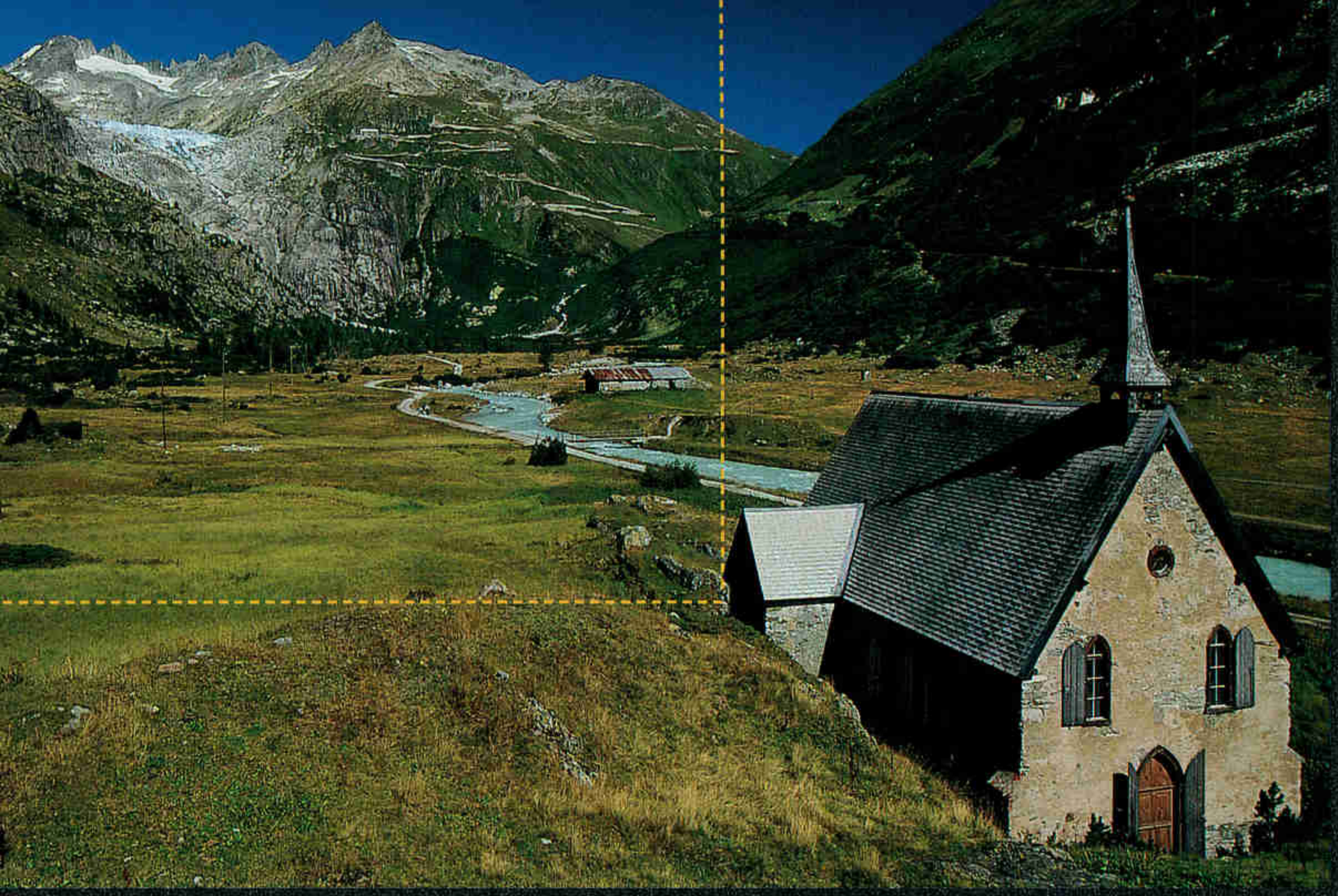
INSTITUT POLYGRAPHIQUE S.A., ZURICH

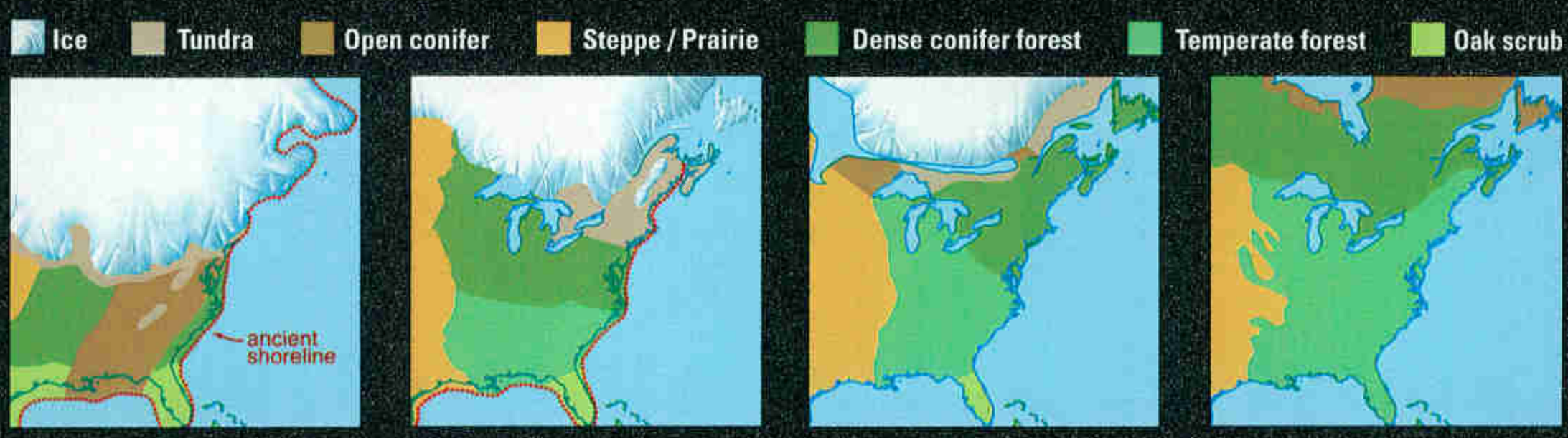
## Looking back through an icy lens

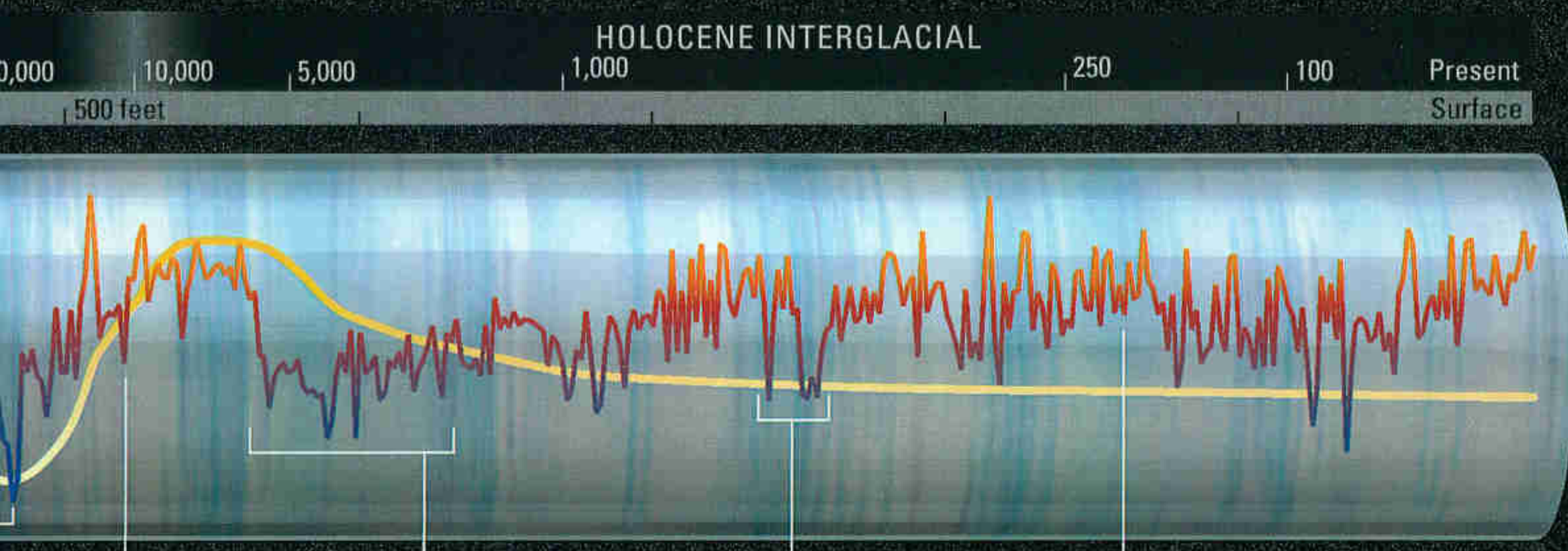
Just under 150 years ago the Rhone Glacier in Gletsch, Switzerland, was among the Swiss Alps' most spectacular sights (above, in an 1849 daguerreotype). Today, seen from the same angle (right), the glacier is a much smaller patch halfway up the mountains. Within the past century and a half, glaciers have retreated worldwide. However, from decade to decade some may advance, as those in Scandinavia are doing today, probably from increased precipitation. The melting of glaciers and ice caps, along with thermal expansion of ocean water, has caused sea level to rise four to ten inches over the past century.




The rise and fall of temperatures over the past 750,000 years in what is now Tibet is revealed in a thousand-foot-long ice core—the longest ever retrieved from the mid-latitudes. Samples of the ice were cut from various levels, and each sample's content of a particular oxygen isotope was measured. Evaporating water leaves behind this isotope, so larger amounts of it indicate higher air temperatures for that period. On the ice core chart above, the derived



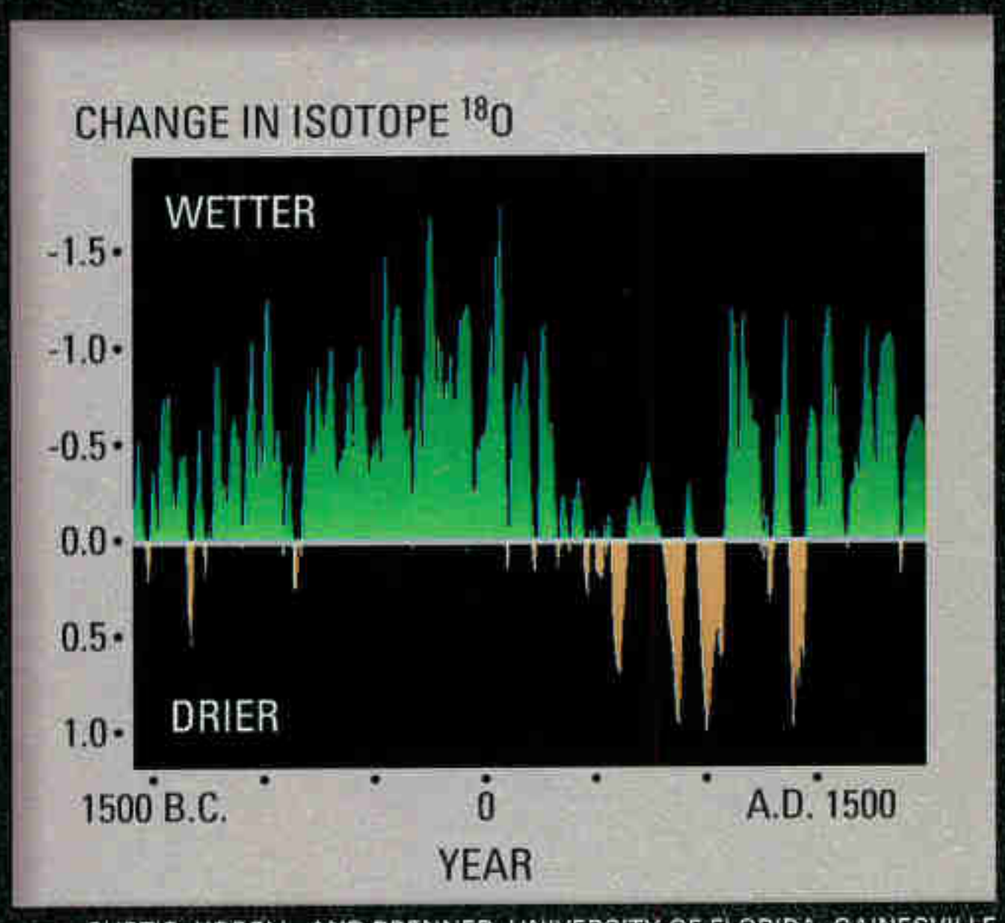



MAPS: JONATHAN ADAMS, OAK RIDGE NATIONAL LABORATORY; ICE DATA: LONNIE G. THOMPSON, OHIO STATE UNIVERSITY

air temperature is superimposed on the levels of solar radiation reaching Earth, based on accepted 100,000-year Milankovitch cycles. The most ancient ice record is greatly compressed—thinned by the enormous weight of the ice above it.

In mid-latitude North America (maps, above) the increase in solar radiation following the last glacial epoch brought about a return of plant life as ice retreated.

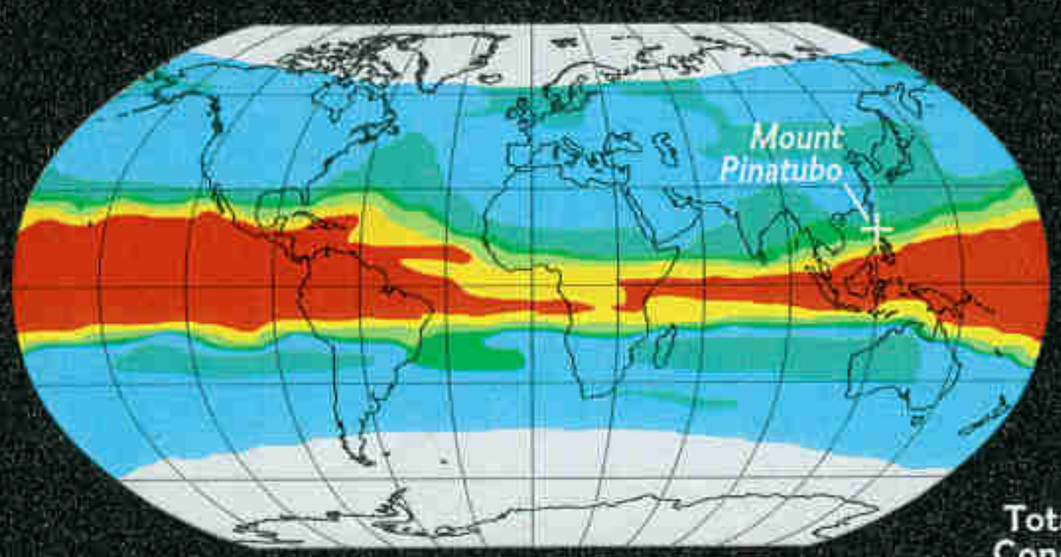



CURTIS, HODELL, AND BRENNER, UNIVERSITY OF FLORIDA, GAINESVILLE

Mud at the bottom of Punta Laguna on the Yucatán Peninsula has a tale to tell, say researchers at the University of Florida. Measuring oxygen isotopes in the carbonate shells of freshwater invertebrates, they can tell the ratio of evaporation to precipitation and thus how wet or dry the climate was in the past. Dry periods are thought to have contributed to the collapse of Classic Maya culture.

# Upheavals for the Maya

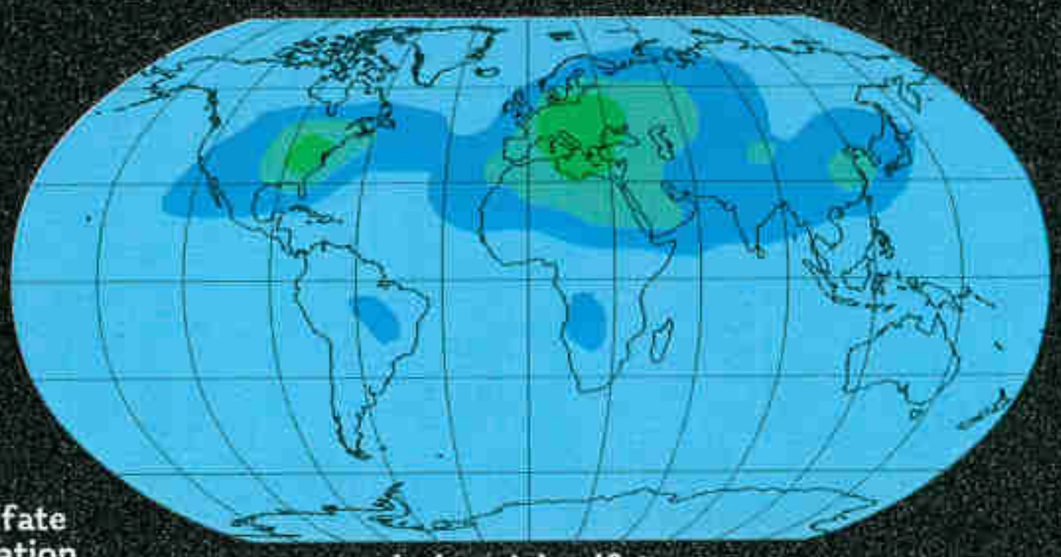
Praying for rain, farmers in the Mexican village of Yodzonot Laguna present food offerings to Chaac, the Maya rain god. Flanked by a Maya priest, David Cocom Cahum holds out a chicken to be dedicated. In a tradition mixing age-old rituals and Roman Catholicism, the men spend the day chanting prayers, preparing breads of cornmeal and ground squash seeds decorated with Christian symbols (above), and sharing a feast. The bread is baked in a large pit lined with hot stones. Called the Cha Cha'ac, this and similar ceremonies have been performed for centuries on the hot, flat Yucatán Peninsula, where corn—"sunbeam of the gods"—is still grown as a staple food and for drink. Fears of too little rain are well-founded. Recent studies suggest that sustained drought may have led to the demise of Classic Maya civilization, which flourished between A.D. 250 and 900.




Mount Pinatubo sulfate

Total Sulfate Concentration

Low High

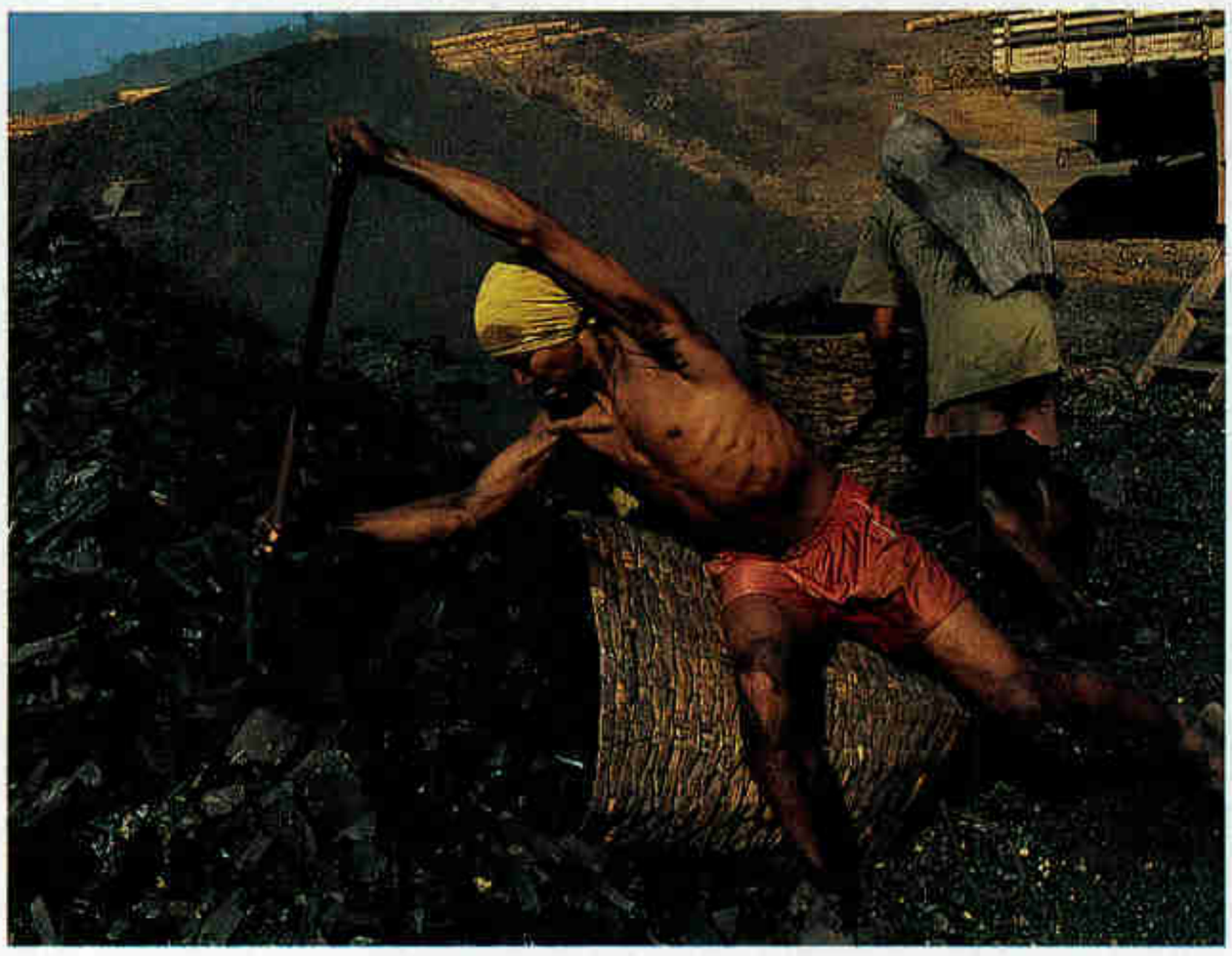


Industrial sulfate

Following Mount Pinatubo's 1991 eruption, tons of sulfur dioxide were carried into the stratosphere and transformed there into droplets of sulfuric acid. Spread around the globe, this aerosol blanket scattered sunlight back into space and absorbed heat from Earth, cooling the planet's surface. Data from Pinatubo have helped scientists improve climate models by clarifying the role of sulfate aerosols, including those produced by industrial pollution, which cool parts of the Northern Hemisphere, as shown in this model.

PINATUBO DATA: NASA; INDUSTRIAL SULFATE DATA:
JOYCE E. PENNER, UNIVERSITY OF MICHIGAN, ANN ARBOR

# Aerosols bring short-term cooling



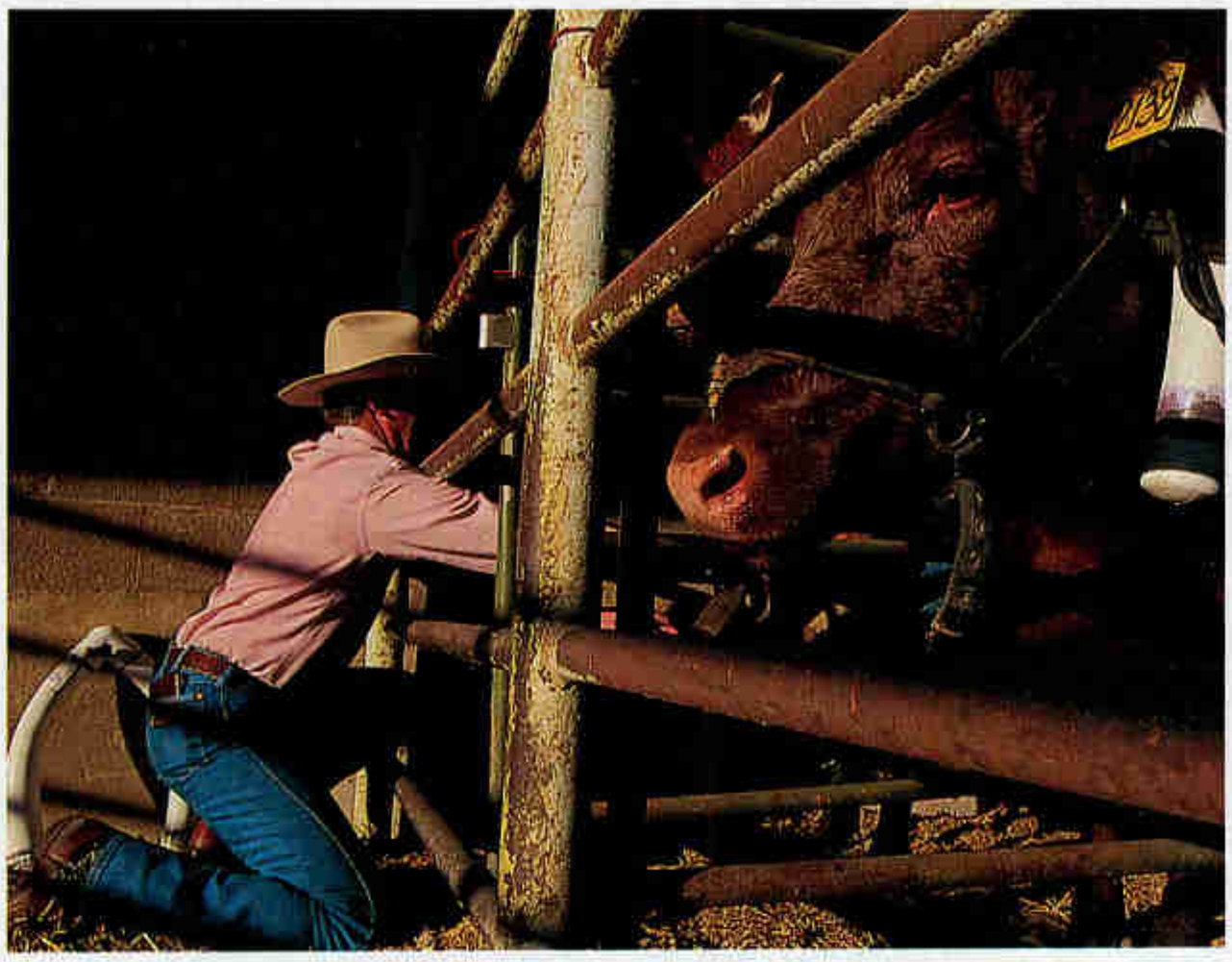
Left homeless by the 1991 eruption of Mount Pinatubo in the Philippines, Lolita Mechado begs for money along a road within sight of Mount Arayat, a long-quiet volcano. She spends much of her time in a government-run refugee settlement. The effects of the Pinatubo eruption went far beyond the country, however, as some 20 million tons of sulfur dioxide were hurled into the stratosphere and circulated around the globe, cooling the planet's surface for two years. Industrial emissions, by contrast, do not reach the stratosphere and thus have a more localized effect. Such aerosols wash out of the atmosphere within weeks if their source is removed, but $CO_2$ can remain for a century, a situation aggravated by the cutting of Brazilian rain forest, the world's largest land-based absorber of $CO_2$. One-third of Brazil's trees have been cut, some to make charcoal for energy needs (above).

Burning forest depletes a carbon-absorbing mechanism, and

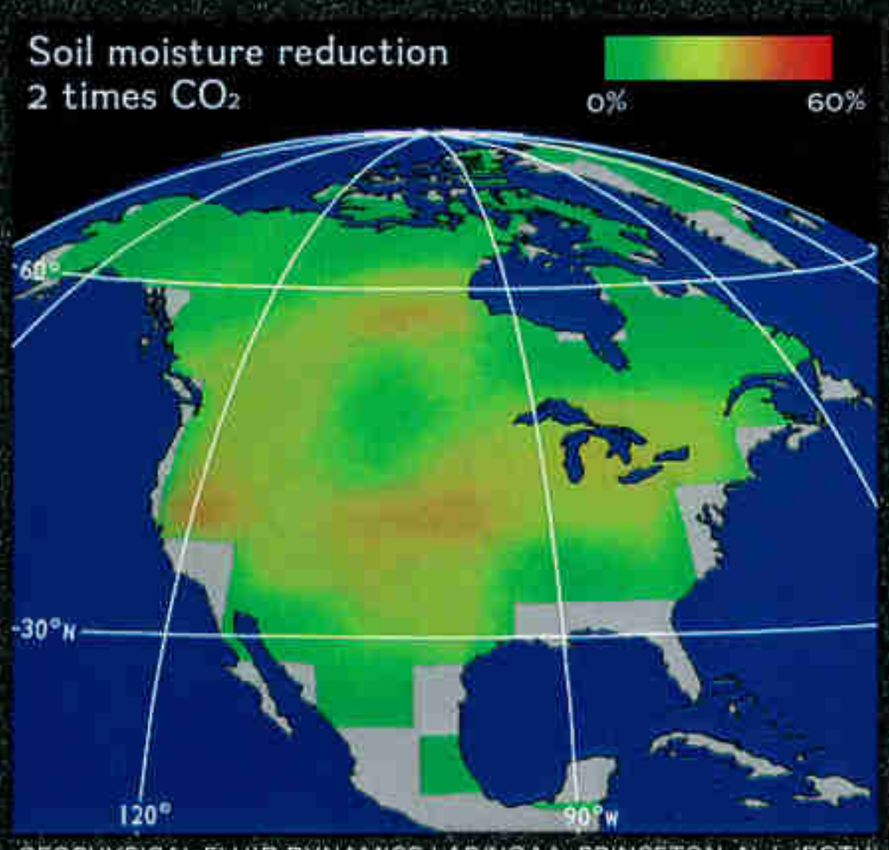
He fought it with a water can. But after two days defending the perimeter of a pasture, Antônio Lopes da Silva surrendered to a raging brush fire. The blaze started six miles away as Brazilian rain forest was being cleared for ranching—just as this pasture had been. Says Stanford University climatologist Stephen Schneider, "Deforestation accounts for about half the buildup of carbon dioxide since 1800."

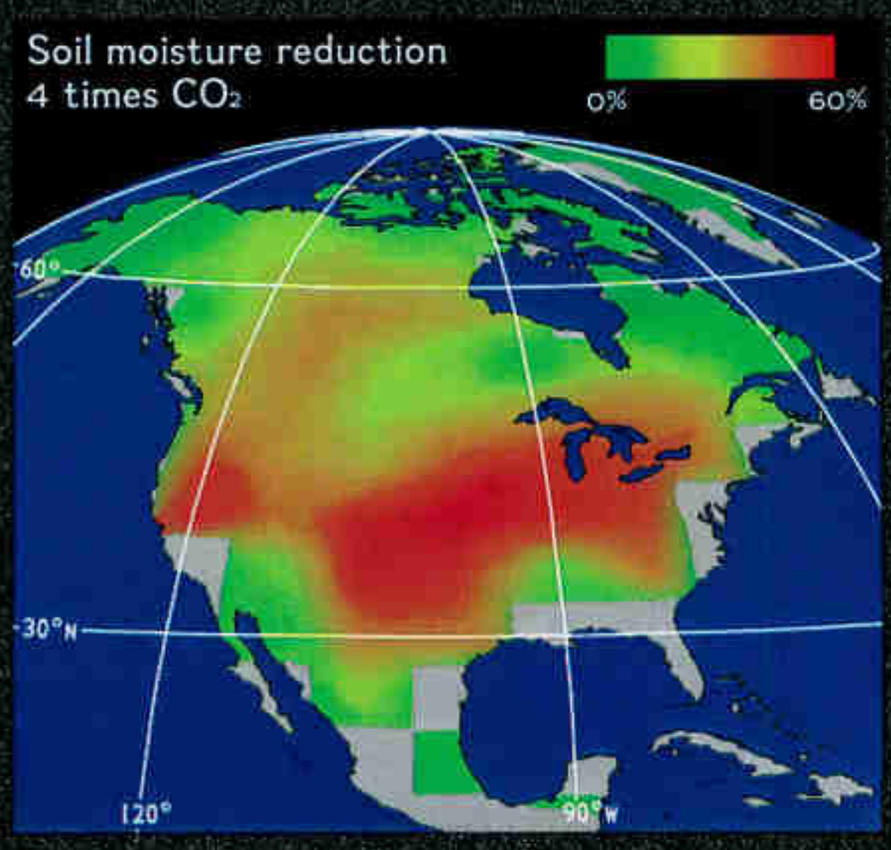
using the land to raise cattle creates a new source of methane.

# Open-air research



To get a ground-level view of climate model projections, scientists at Duke University and Brookhaven National Laboratory sought to create a world with 50 percent more $CO_2$ in the air. In a 14-year-old pine forest near Durham, North Carolina (above right), the gas is pumped through pipes into circles of trees. "Photosynthesis has been enhanced by 50 to 60 percent," says Brookhaven's David Ellsworth. But the effects do not discriminate between plants. Tree-choking weeds also benefit—another example of how humankind's manipulation of the environment can have unexpected consequences. At Utah State University (above) Kenneth Olson monitors cattle breath, seeking to reduce exhaled methane—a greenhouse gas more potent than $CO_2$—through better feed. Methane emissions have increased five times as fast as $CO_2$ since the industrial age began.




GEOPHYSICAL FLUID DYNAMICS LAB/NOAA, PRINCETON, N.J. (BOTH)

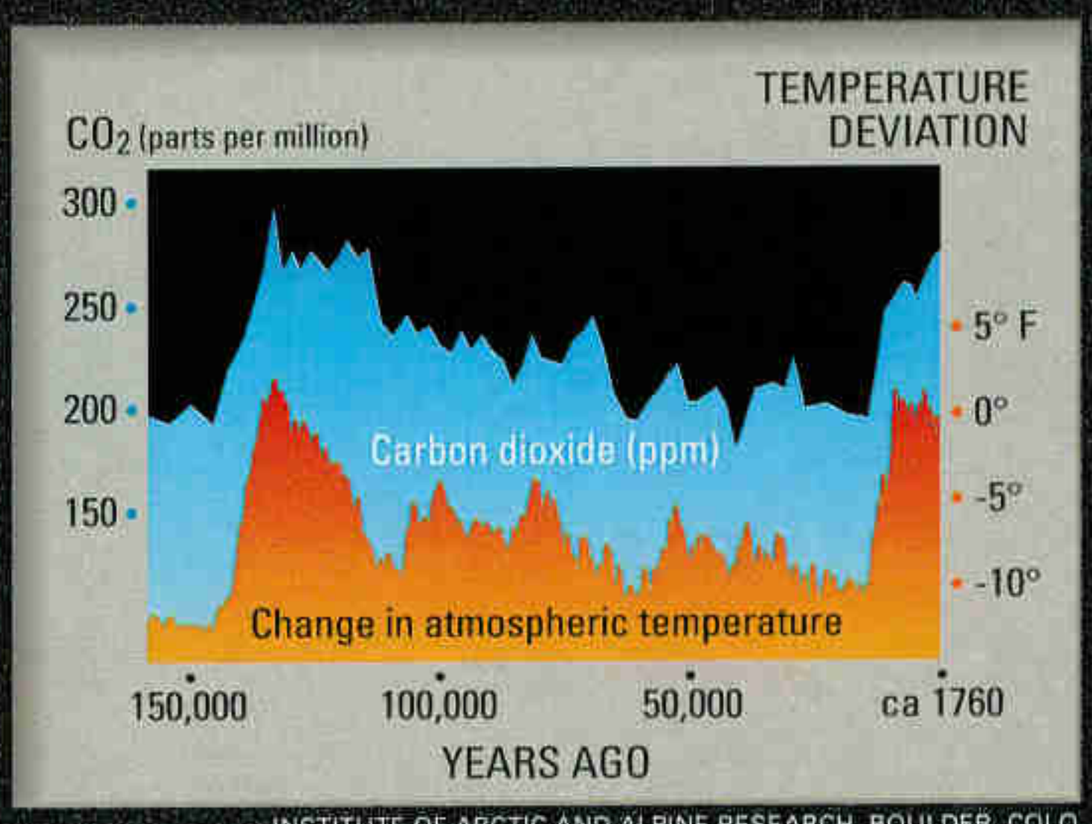
Farming conditions in the mid-latitudes will worsen if $CO_2$ continues its present climb, according to the GFDL/NOAA model. When it doubles, perhaps in 50 years, summer soil moisture is projected to decline in much of North America (left, in yellow). Fifty more years will greatly intensify the effect.

## $CO_2$—a hot topic

Pushing their way through emerging cities like Barakar, India (right), automobiles carry unwanted cargo—$CO_2$ emissions. Since the late 1700s, the burning of fossil fuels and other human activities have increased atmospheric $CO_2$ concentrations more than 30 percent. While the amount added to the air by humans, roughly 7 billion metric tons a year, is a tiny fraction of the total held by the atmosphere—750 billion tons—and an even smaller figure compared with that held in the oceans—about 35 trillion tons—it remains a significant amount. The reason: Natural processes are in balance, drawing about as much $CO_2$ from the air as they deposit. Human activity, however, only adds $CO_2$.

Much remains to be learned about Earth's carbon cycle and the role of the oceans as a "sink" for $CO_2$. Despite such uncertainties, the computer programs used to model Earth's climate are improving rapidly. Current models do well in simulating seasonal variations and climate over thousands of years, leading most scientists to take their overall projections seriously.

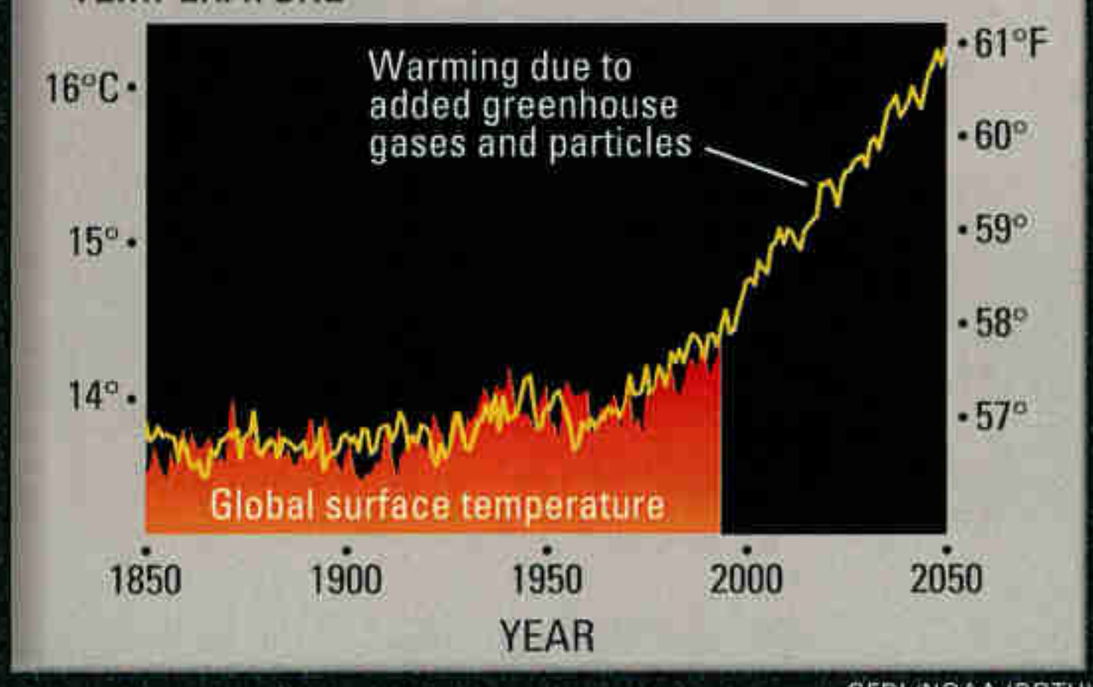

**PREMODERN $CO_2$ LINKED TO TEMPERATURE**




INSTITUTE OF ARCTIC AND ALPINE RESEARCH, BOULDER, COLO.

Antarctic ice-core data show the correlation between $CO_2$ and temperature. The $CO_2$ rise in the past 200 years has been as great as the natural change from glacial to interglacial times.

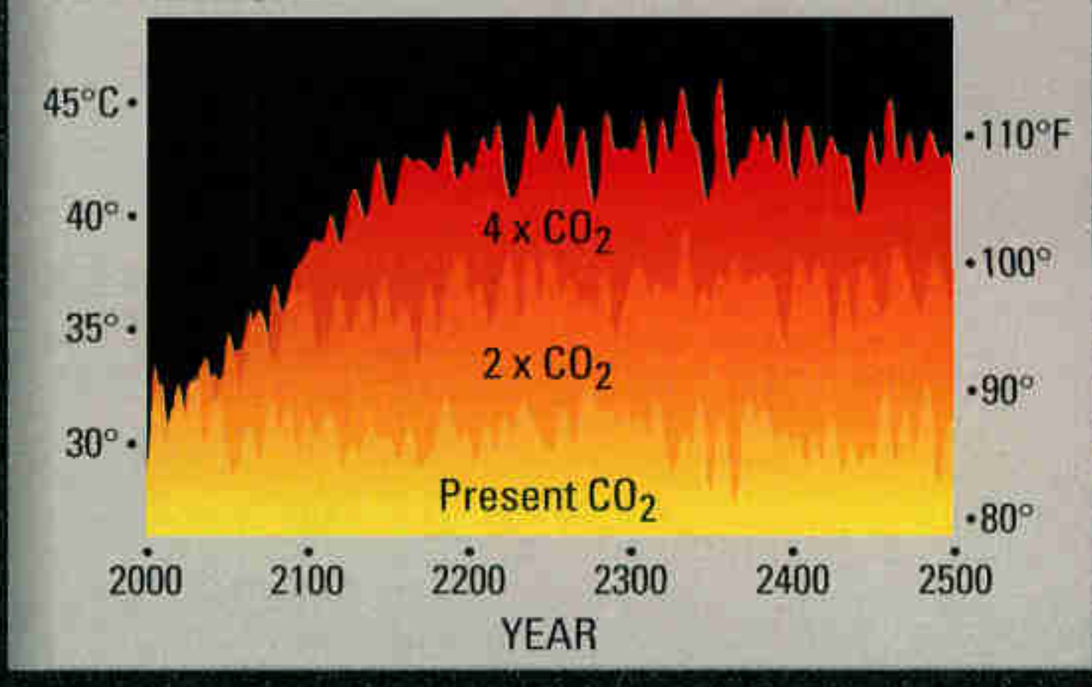

## CONTINUED WARMING FORESEEN




GFDL/NOAA (BOTH)

Using greenhouse-gas data since 1850, the GFDL/NOAA model produced temperature estimates close to actual readings. With rising $CO_2$, it projects, temperatures would continue upward.

## STEAMY SUMMERS FOR SOUTHEAST U.S.




Given an expected doubling of $CO_2$ by 2100, July temperatures in the Southeast U.S. (expressed as an average of day and night readings) would approach 100°F, a 20 percent increase over today's.

# A global effort

BOB SACHA

Picking up the pieces in Madhya Pradesh, India, a girl gathers coal that drops off trucks bound for an electric power plant. With limited alternative resources, India uses coal—the most abundant fossil fuel—to meet about three-quarters of its commercial energy needs. China too depends upon huge deposits of coal for most of its energy. In Fengjie, a major trading port on the Yangtze River (above), workers haul coal to barges for delivery to power plants downriver. In the face of worldwide demands to reduce greenhouse emissions, developing countries are torn between going along or improving immediate living standards. In the long run living standards for citizens of every nation will require not only a better understanding of Earth's climate but also a clearer commitment to future generations. □

**For more on climate change, go to www.nationalgeographic.com and click the 2000 icon.**

# Return

# of the Gray Wolf

By DOUGLAS H. CHADWICK

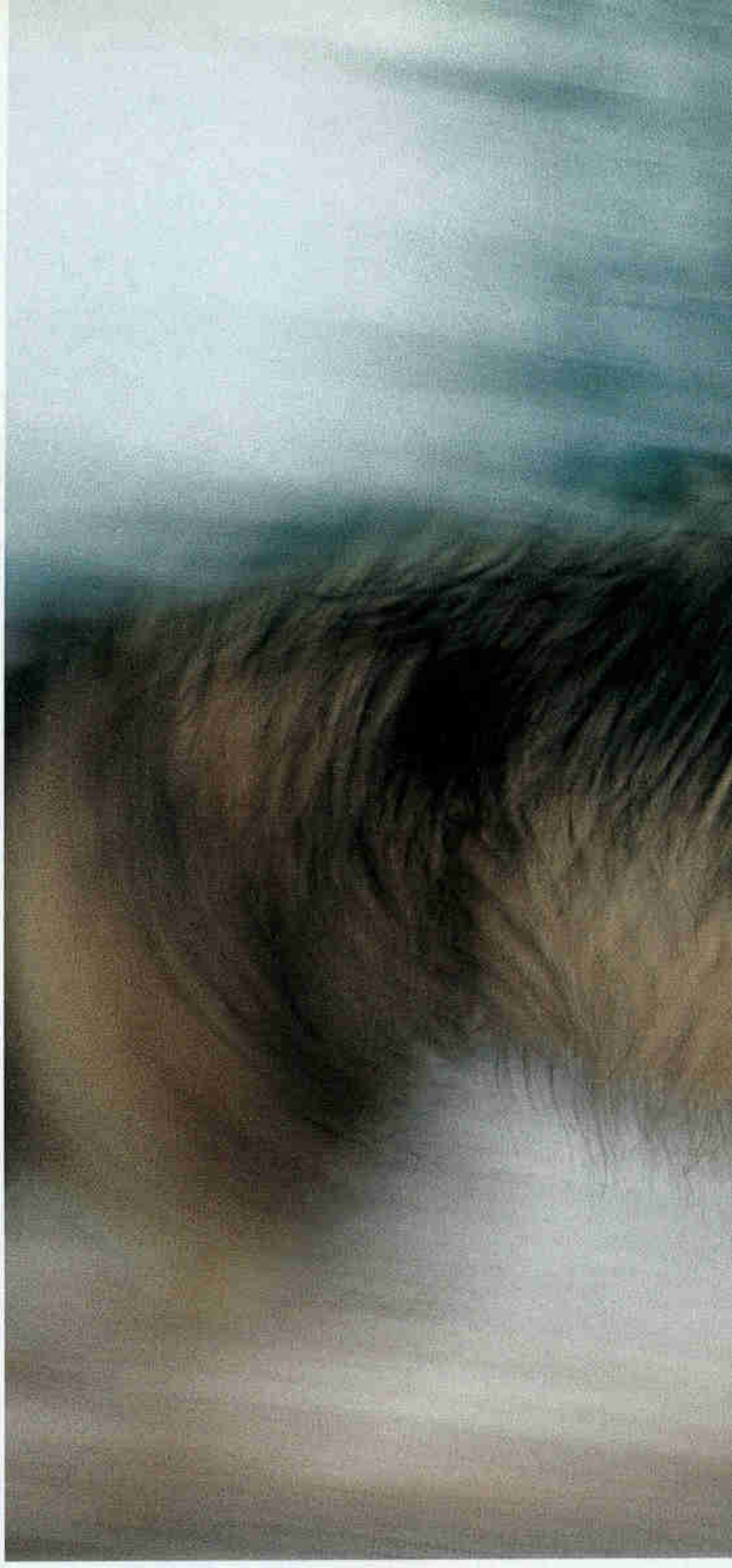
Photographs by JOEL SARTORE

For thousands of years the gray wolf was one of the most widely distributed mammals on Earth. By the early 1900s people had trapped, poisoned, and shot it almost to extinction in most parts of the United States. While a federal plan to reintroduce the wolf to some of its former U.S. habitats has proved hugely successful, controversy swirls on the ground and in the courts.

The big bad wolf. The wolf at the door. Throw him to the wolves. These are classic characterizations. Yet wildlife biologists insist that wolves are intelligent, loyal, and gregarious. So which is it? As this shot of a captive wolf makes clear, it depends on your point of view.

Wolves wandering across Minnesota's great white north have fared far better than their cousins elsewhere, partly because thick forest and the lack of roads barred trappers. With packs flourishing, problems arise, such as a growing incidence of wolves killing livestock and domestic dogs.

**A captive wolf in Yellowstone can't escape, nor could its forebears, which got squeezed wherever settlers staked a claim. As people wiped out their natural prey, wolves attacked livestock instead. To protect their land and livelihood, ranchers reached for their rifles.**



WOLVES EAT MILES, consuming them with a tireless trot. This wolf was black and glided like a silhouette across the distant April snowfields. Focusing her telescope, the young researcher said she thought it was the alpha male of the pack that had colonized the Blacktail Deer Plateau here among the northwestern folds of Yellowstone National Park. To avoid any hint of attachment to North America's most controversial predators, the biologists had been instructed not to give names to individual animals, so this wolf was known simply as Number Two.

The wolf was headed for the carcass of an elk his pack had brought down the day before. Ravens scattered as he drew near. Two scavenging bald eagles flapped heavily up into an aspen. But a solitary coyote, tugging scraps off the bones, never looked up. It should have. Since officials began reintroducing wolves to Yellowstone in 1995, 69 years after the last were trapped out, the wolves have killed half the coyotes where the species' ranges overlap, causing the smaller canines to scale back their territories, movements, and social groups.

Now, suddenly, the black wolf broke into a run. At the last moment the coyote dashed away across the side of a forested knoll. The next time it came into view, the wolf was 40 feet behind and closing. Moments later I saw them once more, barely 20 feet apart. They were lying down, though, and both were wagging their tails. Then the wolf stood to face the coyote, lowered its forequarters, and wobbled its head—a canine invitation to play.

"Well," said the researcher, "I guess that's not Two. It has got to be Joey."

Joey?

"I mean Number 56."

The gray wolf, *Canis lupus,* is still common in Alaska and Canada. But elsewhere on the North American continent a relentless war against these animals was waged with rifles, traps, and poisons for more than 300 years. In 1967 experts declared that the species was facing extinction south of Canada. In 1974 the gray wolf finally won protection under the Endangered Species Act. More recently, it has emerged as one of the most popular symbols of imperiled wildlife. T-shirts, bumper stickers, and posters proliferate in praise of the beast.

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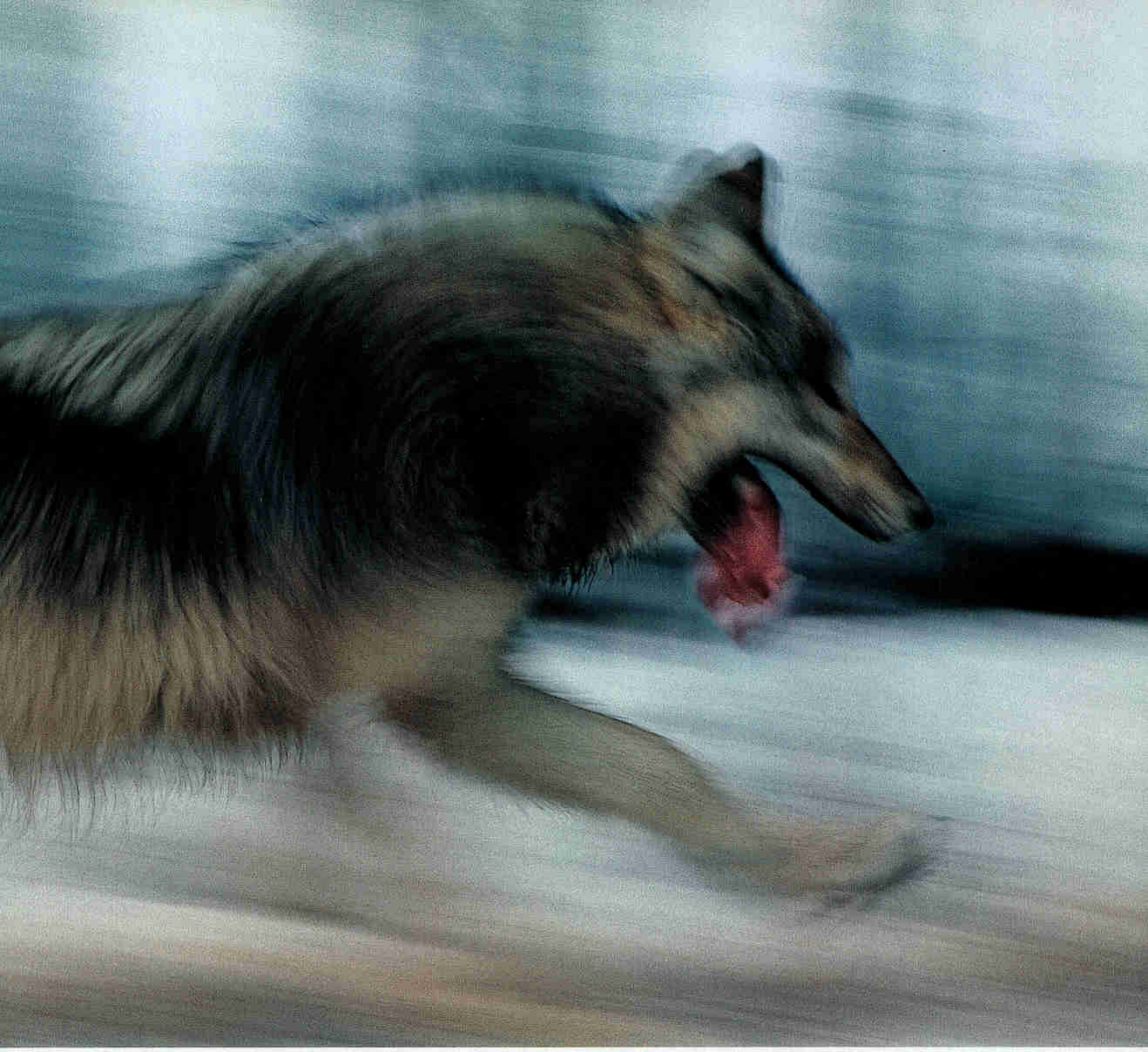
Writer DOUG CHADWICK and photographer JOEL SARTORE teamed up to produce "Sanctuary: U.S. National Wildlife Refuges" for the October 1996 issue, as well as a National Geographic book on America's endangered species entitled *The Company We Keep.*



To find out how the wolves themselves are faring, I had set out to track their relocation in the Yellowstone backcountry and the wildlands of central Idaho, their unassisted emigration from Canada into northern Montana, and their natural expansion in Minnesota. I learned how to read fresh sign. I howled with biologists under the stars to prompt wolf packs to howl back and thereby reveal their location. And now I was watching Number 56, the unofficial "Joey" known to be the first in fun and last in battle, in playful standoff with a coyote.

Like humans, wolves display a variety of temperaments and psychological quirks. Their family structure more closely resembles ours than do those of many primate societies. Loyalty and affection toward kin are two of a wolf's most observable characteristics. Curiosity is another. The ways wolves learn, communicate, and amuse themselves stretch our definition of animal capabilities. If those traits also describe dogs, it is because our Stone Age ancestors produced humankind's best beloved companions, *Canis familiaris,* by domesticating *Canis lupus.* Genetically the two are still the same canine, quite capable of interbreeding.

The combination of strength, smarts, and coordinated pack behavior made wolves extremely successful. Found across Europe, Asia, and North America from the high Arctic to central Mexico, wolves for millennia were the most widespread land mammal after humans. Largest of the wild canids at 80 to 120 pounds, this carnivore also ranked as one of our keenest competitors for meat. As people became

dependent on livestock, however, respect for the wolf gave way to loathing.

In medieval times *The Book of Beasts* warned readers that the devil himself "bears the similitude of a wolf, he who is always looking over the human race with his evil eye, and darkly prowling around the sheepfolds of the faithful." The sheer extravagance of antiwolf propaganda over the centuries reveals the wolf's grip on our psyche even as American Indian legends celebrate the animal as a deity and founder of human clans. For better or worse, these top predators with the haunting song keep reminding us of something in ourselves.

EXCEPT FOR THE SOUTHEASTERN United States, the domain of a slightly smaller species known as the red wolf, *Canis rufus*, the gray wolf originally ranged coast to coast across North America. Gray wolves numbered in the hundreds of thousands and came in a variety of subspecies: the eastern timber wolf, midland wolf, northwestern wolf, Arctic wolf, and Mexican wolf, whose territory took in the U.S. Southwest.

But wherever Europeans settled in the New World, wolf extermination followed. For many years government agencies paid cash bounties, and federal hunters tracked down any rumor of survivors—even inside parks and refuges. One private bounty hunter spent six months laying traps across 2,600 square miles of the South Dakota–Wyoming borderlands to get a single holdout—and caught it. Erased from most of the East long before the end of the 19th century, gray wolves were gone from the West by the 1930s. By the 1960s the only ones alive south of Canada were a handful holed up like desperadoes deep in Mexico's Sierra Madre, a score on Isle Royale out in Lake Superior, and 300 to 700 in northernmost Minnesota.

Joe Baltich, Sr., former chief of police in the northeastern Minnesota town of Ely, showed me an old photo of 11 wolves dangling from a pole next to a bush plane parked in the snow. The era was the 1940s. Minnesota had a hefty bounty on wolves then, and Baltich, 15 years old at the time, had just helped his brother shoot eight from the air. "We made part of our winter living this way," he recalled at his lodge, looking out on a frozen lake near the Boundary Waters Canoe Area Wilderness. "We also trapped wolves with our father."

The bounty ended in 1965, and Baltich's enthusiasm for traplines gradually gave way to grudging admiration for the wolf.

Baltich's son, Joe Jr., came over to sit with us. "I used to trap wolves with Dad," he said. "Now you could say we trap tourists, using wolves as bait." Ecologically oriented tours are the family's specialty these days, and the local wolves are definitely a prime attraction. "Just finding fresh droppings on one of the trails we groom for cross-country skiing gets visitors excited," Joe Sr. said. And Joe Jr. added, "This isn't really about wolves. It's about how people change."

Many species in jeopardy have specialized habitat requirements or reproduce very slowly. For them, recovery can be a drawn-out, fragile affair. Wolves are tough, ecologically elastic, built to breed quickly and explore widely. Radio-collared individuals dispersing from their home territory have been tracked 550 miles. Timm Kaminski, an Idaho biologist, calls wolves long-range fur missiles. Wolves can make do in almost any kind of habitat that provides food. Their fate in the modern world depends much less upon biology than upon our opinion of them.

Because opinions do change, Minnesota supports more than 2,000 wolves today, and the population is expanding into northern Wisconsin and Michigan's Upper Peninsula, which sustain at least a hundred animals each. Ely boasts a new institution called the International Wolf Center. The 50,000 folks a year drawn to its live wolf enclosure, museum exhibits, and field classes bring an estimated three million dollars into the local economy.

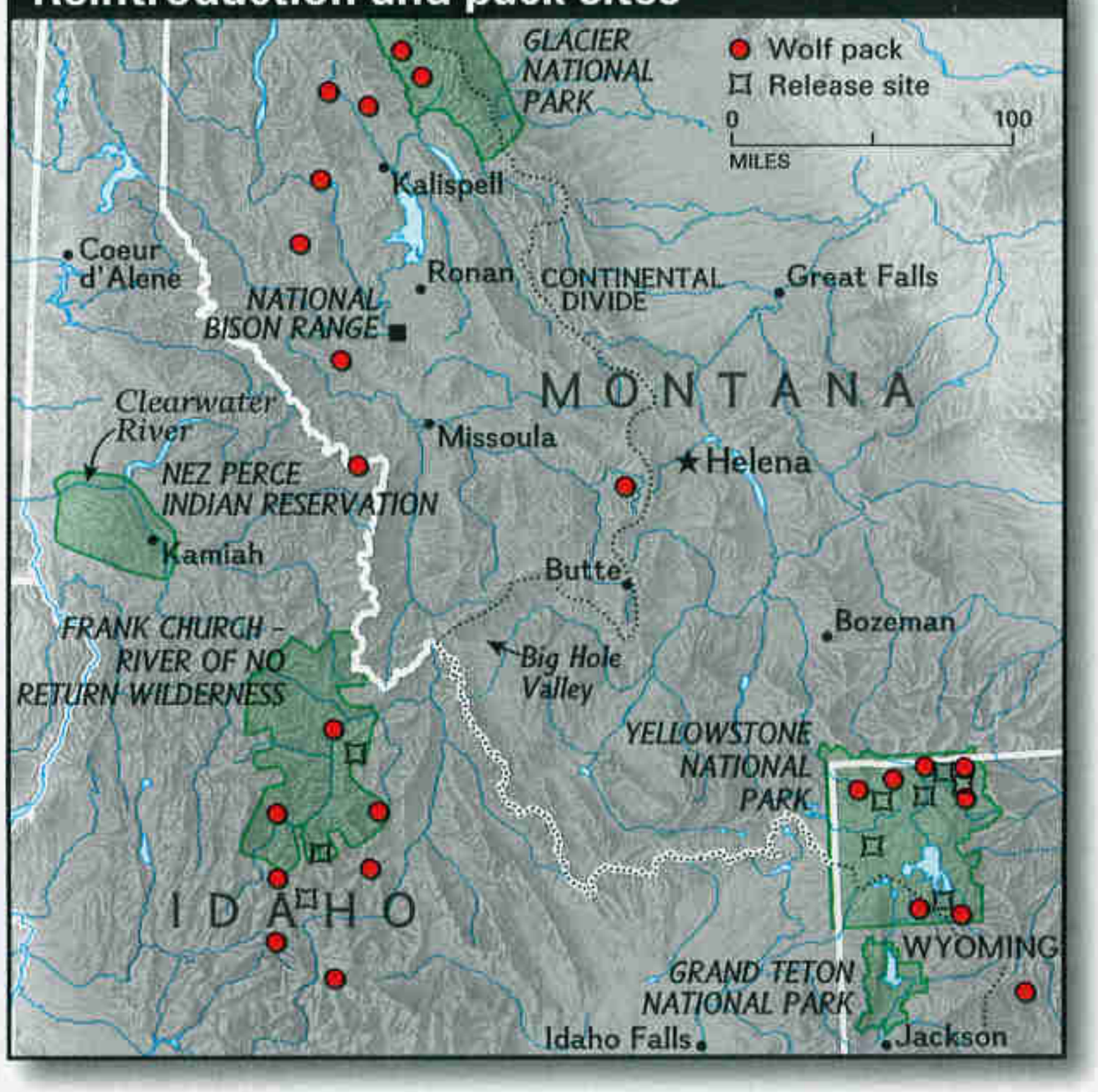
I can think of no creature whose fortunes more clearly define the transformation of our attitudes toward nature. Ed Bangs, the U.S. Fish and Wildlife Service's (FWS) recovery coordinator for the species in the lower 48, told me, "Acceptance of wolves represents a social shift equal to the end of market hunting."

But the old image of wolves as leering arch-villains has been slower to dissipate out in cowboy country, where great-granddaddy's stories of notorious stock killers are still fresh. One reason the Old West spawned such tales seems to be that the carnivores didn't have much else to dine on then. Unregulated shooting had wiped out 60 million bison and pushed elk, pronghorn, and even resilient deer to all-time lows. Wolves turned to tame meat, were purged, and

# Recolonizing a continent

Wildlife biologists once divided North America's gray wolves into 24 subspecies; now they recognize only five (top map). After sanctioning the slaughter of wolves for decades, federal agencies in 1995 launched an ambitious project to restore the animals in parts of their former range. The plan involved airlifting wolves from Canada into Yellowstone National Park and the Frank Church Wilderness, as well as protecting wolves moving into Montana on their own. Though wildly successful—there are some 90 wolves in Yellowstone, 70 in Idaho, and 75 in Montana—the program now faces a challenge from a federal judge who has declared the project illegal.


## Reintroduction and pack sites



remained absent for nearly half a century until a few Canadian wolves during the 1980s rambled down the Continental Divide to colonize a portion of Glacier National Park in Montana.

ONE MORNING IN EARLY AUTUMN, a little more than a decade ago, I hiked from my cabin home near Glacier Park to a hidden meadow where I could watch rutting elk. Easing through the pines and frost-burnished aspen, I noticed that I was on a worn path. Something else had taken to looking over this clearing from the forest edge—something whose droppings held fur. Farther on lay hide scraps, scattered leg bones, trampled-out patches, and skulls. It was like stumbling upon the hunting camp of some long-lost tribe. The standards of fitness for hoofed herds in these mountains had just been raised a couple of notches.

Offshoots from the pioneering wolves of Glacier founded other packs southward along Montana's Rocky Mountains. Then, in 1995 and 1996, in a move as packed with symbolism as with biological importance, FWS officials chose to speed the process by transplanting a total of 31 Canadian wolves into America's oldest national park, Yellowstone, and 35 more into central Idaho's Frank Church–River of No Return Wilderness. The federal wildlife service will define the western population as recovered as soon as two things happen: Ten breeding packs establish themselves in each of the two reintroduction areas and remain together for three successive years, and, second, ten packs establish themselves in the Montana region where natural colonization continues.

All three ecosystems had at least half a dozen packs by 1997, putting the recovery ahead of schedule and under budget. Yellowstone Park officials figure that more than 20,000 visitors have sighted a wolf thus far, and studies predict that the animals' presence will generate millions of dollars in tourism spending in the greater Yellowstone region alone. The Lake Superior population is already at a level many consider secure. With luck, *Canis lupus* will disperse itself off the endangered list within the next few years—a big success not only for the wolf but for the Endangered Species Act itself, often criticized as unwieldy and ineffective.

The wolf's steady comeback in the Rocky Mountain West and in the Lake Superior region has encouraged scientists and wildlife advocates to consider the feasibility of restoring eastern timber wolves to New York State's 5.8-million-acre Adirondack Park; a poll shows eight out of nine New Yorkers favoring the move. Olympic National Park in Washington is being evaluated as another potential home for the wolf. Meanwhile, gray wolves have been introducing themselves a few at a time to northern Idaho, and some have even been seen in the wide-open Dakota prairies.

Mexican wolves, the most critically endangered subspecies in the lower 48, may have slipped from existence in the wild. However, a population of more than 175 has been bred in captivity from seven of the last known to exist. Federal biologists intend to start releasing some this year into national forestland spanning the Arizona–New Mexico border.

Before loosing any wolves to bolster the Rocky Mountain population, the FWS distributed 750,000 information documents, held more than 130 public hearings, and collected some 160,000 comments and letters, the most ever received on an endangered species issue. Sentiment ran strongly in favor of reintroduction. Somewhat surprisingly, surveys found that most respondents within the affected states of Montana, Idaho, and Wyoming also favored it. Nevertheless, hunters envisioned a massacre of game. Ranchers forecast the demise of their way of life. The whole idea of giving wolves a helping hand had cowboys marching in the streets.

At a rally against the Endangered Species Act in Ronan, Montana, placards read: "Wolves Eat Deer, Elk, Cattle, and Tax Dollars." Passing me a brochure with a photo of a mutilated deer, Troy Mader of a Wyoming-based outfit he calls the Abundant Wildlife Society of North America said, "Alaska and Canada have plenty of wolves. How can the government say they're endangered and try to stuff them down our throats here? I've dug up old news clippings, and they show large numbers of wolves killing stock and things like mail carriers getting chased by wolves. Wolves are destructive, and we should have the option to control them using poison and aerial hunting. People's rights have to come first."

Despite the nay-saying, the transplant plan won public support, in part because Defenders of Wildlife, a private *(Continued on page 90)*

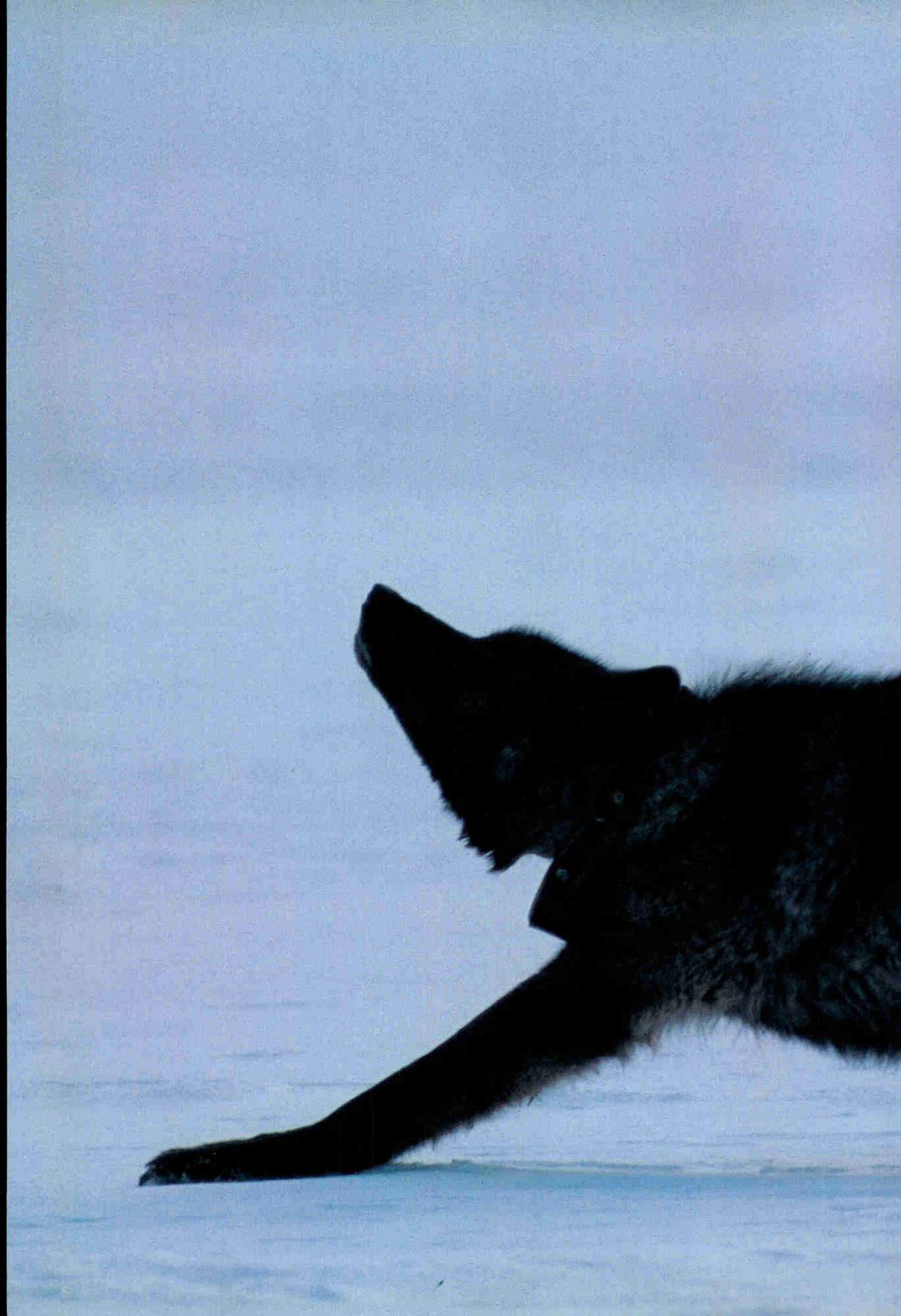
RICK RICKMAN (BOTH)

**Proceeding with caution, members of Yellowstone's wolf project use salmon nets to snag Number 27, a recent transplant from British Columbia. Upon arrival wolves were penned for ten weeks to acclimate them to their new habitat and to discourage them from bolting back home when released. After safely sedating a wolf pup, volunteer Dan MacNulty shoulders it to another pen, last stop before it lopes into the wild.**

Elk hadn't seen wolves in Yellowstone since 1926, yet when the hunt resumed recently, they knew what to do. Clustering, they seek safety in numbers, while wolves angle to snatch a weak member of the herd. How will the park's 90 wolves affect its 35,000 elk? It's too soon to tell.

# At home on their range

Why do wolves howl? It's their way of saying, "This is our turf," or, "Where's the rest of our pack?" or, perhaps, "We've found food." Feasting on a bison carcass (below), a young wolf flashes a "keep your distance" look. The striking similarities between wolves and dogs—their build, their behavior, even the way they stretch (right)—have led many people to crossbreed them, sometimes with disturbing results. One such hybrid offspring heard a sofa spring squeak, then tore the furniture's upholstery to shreds while searching for a mouse. "Want a pet wolf?" says one expert. "Get a dog."



*(Continued from page 82)* conservation group, offered to compensate ranchers for any livestock lost to wolves. Moreover, the feds eased protection normally afforded endangered species, ruling that ranchers in the reintroduction areas could shoot any wolf caught attacking their livestock.

But ranchers and several environmental groups separately challenged the transplant effort in court. The environmentalists feared that lessened protection for wolves could become a death sentence for existing natural populations. The ranchers' lawyers contended that the Endangered Species Act forbids placing an "experimental population" in the range of an established one. Last December a federal judge in Wyoming agreed with both arguments and ruled the introductions illegal. He ordered all the transplanted wolves deported but stayed his order pending appeals. Awaiting further rulings, the federal recovery team has said that if the original decision is upheld, the only way to remove the wolves will be to kill them.

Rather than dwell on the challenges raised by the recovery effort, let's consider the case of two wolves caught up in it—a gray male yearling and a young black female. They were going about their lives in separate parts of the Canadian bush when each was captured, drugged, crated, and—after protracted delays—flown with other wolves to a release site in Idaho. This was in early 1995.

A year later, during the spring of 1996, the male, labeled B7, and the female, B11, wandered eastward about a hundred miles from Idaho to Montana's Big Hole Valley, where, after avoiding trouble for several months, they were implicated in the death of a heifer.

**Behaving like a bunch of wolves, members of Yellowstone's Rose Creek pack tussle in play. Most wolf packs are led by a breeding pair—an alpha male and female, both of which care for pups and fight to defend their family. They also lead the hunt and eat the choicest chunks of carcass. Juvenile members of the pack have a pecking order too, which often forces some of the members to leave, find mates, and start their own packs.**

An agent from the U.S. Department of Agriculture's Wildlife Services branch—formerly called Animal Damage Control—lifted off in a helicopter to dart the pair with immobilizing drugs. He hit B7, but the dart struck bone and failed to inject, and the male escaped. His mate went down. The female was taken to a part of Idaho 160 miles distant and released. Eleven days later, she was back in the Big Hole with B7.

Months passed before they were captured and returned to the Idaho backcountry, where a newly built pen with fencing 12 feet high was to keep them until spring, when they would be released farther north. But B7 went over that fence. For two weeks he lingered close by, trying to get back in to B11 or somehow to get her out. Finally he turned east alone.

A cowboy spotted him in the Big Hole in early April. The wolf was at the edge of a snowy calving pasture, eating afterbirths. It sure looked like trouble in the making. I heard the news and drove all day to get there. When I arrived, Carter Niemeyer, the Rocky Mountain region wolf management specialist for Wildlife Services, had just darted B7 from a helicopter again and was heading in with the wolf strapped to a strut. I helped Timm Kaminski of Idaho's recovery program unload the wolf and examine him. Now three years of age, he was fit and heavy, 105 pounds. Yet his teeth looked like those of an old animal, broken and dulled from biting at the metal pens that had confined him.

The next thing I knew, I was holding B7 on my lap in a pickup truck Kaminski was gunning down the road. I had blood and saliva leaking onto me and struggled to keep a grip on the tensing wolf as the drug began to wear off. We regrouped with the rest of the team to

The chance to glimpse wolves plowing through a Yellowstone winter may attract a few hardy souls, but warm weather brings wolf-watchers out in force. The popularity of tours and wolf classes suggests that the grizzly bear may no longer reign as the park's marquee mammal.

# Razed by wolves

**Two times a day, 15-year-old Hayley Jolma used to bottle-feed her calf, Minnie, on the family ranch in western Montana. Then one night animals attacked and badly mauled Minnie, who had to be destroyed. A necropsy, which required stripping the skin off the calf's back, revealed tell-tale bite marks, confirming that wolves were to blame. "My daughter doesn't understand why wolves can kill her pet but she can't defend it," says Karen Jolma. Wildlife officials shot the local pack's alpha male, leaving Opal, the alpha female (middle), to care for her two pups. Months earlier, a similar attack by Opal's pack prompted federal officials to kill four of its members.**

move B7 into yet another holding cage. Some wolves quaver under such stress, but B7 gave off a steady, low growl like rolling thunder. This animal didn't have it in him to yield.

I visited the Big Hole again to talk with Bob and Arlene Peterson. It was their calving pasture B7 had been eyeing. I half-expected the conversation to gallop straight into the wickedness of predators. Instead I was served a steak dinner at the family's spacious log home.

"I don't hate or blame these animals," Bob Peterson said. "The wolf is just doing what God made him to do. It's not his fault he's part of this federal program."

B7 was flown to a reunion with B11 in the Idaho enclosure, its top now extended with more fencing. In the summer of 1997 they were given one more chance at freedom—their last. If either bothers stock from here on, they'll be killed. But if B7 and B11 can hold on to their new territory and somehow make a home like each had in Canada before they were snatched away, what a tale they will carry in those long-legged bodies and questing eyes.

IDAHO'S WOLF RECOVERY PROGRAM is run by the Nez Perce tribe, partly because angry Idaho politicians wouldn't let any state agencies cooperate with FWS. I went to a springtime powwow in the little town of Kamiah on the Nez Perce Reservation, and on a hillside overlooking the Clearwater River met Ken Bourgeau, Jr., who works in the tribal forestry department. He was putting on a necklace of silver and bone. The cape he would wear with it in the evening's dances had a bushy tail.

"My dad traded for this wolf pelt in northern Washington," Bourgeau said. "Dad taught me to respect every living thing. It honors me to belong to this tribe and be part of bringing back the wolves. This was meant to be, because they were here since the mountains."

Another traditional dancer, Dan Spaulding, added, "Wolf makes the circle whole again."

Other cultures are less sure that every lifeform has a right to exist. Although wolf depredation on livestock in the West has been slight so far, the figures are increasing, raising questions in many minds: What will it be like to have flourishing packs back in the territory? Can we really live with them?

For answers I returned to Minnesota. First day there, I met rancher Julian Brzoznowski, who has had nearly as many wolves taken off his thousand-acre property over the past two decades as exist in the West—at least 200. "These environmentalists," he sighed. "If somebody stole their car, they'd go nuts and want full prosecution. But they don't mind if wolves rob all my cattle." Legal action by Brzoznowski helped spur a revision of Minnesota wolves' status from endangered to the less protected category of threatened in 1978, and the state now pays compensation for wolf damage.

Yet I also learned that Brzoznowski's situation represents an extreme. His ranch, an island of cleared, grassy meadows in an immense forest tract near Canada, happens to be the hub of half a dozen overlapping wolf territories. Statewide statistics tell a far more peaceable story. Within the current range of 2,300-plus wolves lie some 8,000 farms and ranches. In recent years only 70 to 90 farms—about one percent—experienced losses. Records from 1979 through 1996 show an average of 43 sheep and 38 cattle lost to wolves annually, or about one sheep out of every 400 and one cow out of every 6,100 in wolf country. The amount paid out annually to reimburse stockbreeders for wolf damage comes to about $32,000, total, for the state—little more than the cost of a pickup truck, like the one carrying me down a Minnesota road in May.

"Funny how wolves are the focus of so much argument, isn't it?" said the driver, Bill Paul, Wildlife Services wolf specialist for the state, as we sped past pale birches just coming into leaf. "Minnesota has fish-farming operations that individually lose $50,000 a year to birds. When wolf recovery started here, ranchers expected wolves to eat up everything. Now they realize it's not as big a problem as they first thought."

Troublesome wolves in Minnesota are no longer relocated. They are caught in steel-jaw traps and given a bullet to the brain. About 200 go that way every year. As we pulled into Emery Erola's pasture, I reminded myself that Bill Paul's task was to add to the total.

My memory called up the scene here earlier in the week: A mother cow bawling among yellow meadow blossoms, refusing to leave the half-devoured body of her new calf, and Erola, a soft-spoken man of Finnish descent who had no deep grudge against wolves, muttering, "This is starting to really tick me off."

Now Paul looked toward the kill site and

said, "Got a trap pulled out." There were fresh paw prints in the mud and furrows where the trap's chain and anchor hooks had been dragged.

Moments later, Paul found the trapped wolf by a fallen tree at the forest edge. Her foot was torn and two of the bones busted. The fire in her eyes had burned down to ash, for someone had already put a mercy bullet into her chest.

Look closely. I don't mean to rub anyone's nose in the reality of it, but deaths—hard deaths—inevitably come with wolves. For them to live, wild prey must die. When other circumstances cause wild prey to decline, livestock dies. Then certain wolves are destroyed so that people will let other wolves live.

"WE SPENT YEARS EDUCATING the public not to kill wolves," the FWS wolf recovery coordinator, Ed Bangs, once told me, "and a lot of folks hated us for taking the animals' side." Some even threatened Bangs himself. "When we delist the wolf, things will flip-flop. We'll be trying to persuade people to let more of the population be controlled by lethal means, and conservationists will hate us."

Not even Bangs is certain what form wolf management will actually take after recovery and delisting. Authority over the species will then revert to individual states, which may decide to treat it as a game animal. Proposals for hunting and trapping seasons threaten to ignite a whole new round of political wolf wars. A major percentage of the wolves from the Glacier Park ecosystem are already being killed because they disperse into southern British Columbia and Alberta, which permit generous harvests of wolves for fur and sport.

Considering the learning abilities of both wolves and humans, alternatives to future wolf wars exist, at least for small ranching operations. I came upon several during my travels. The most effective are simple improvements in animal husbandry such as moving stock into safer areas during the vulnerable birthing season. Quickly disposing of animals that die from other causes is crucial, as carcasses not only lure predators but may teach inexperienced wolves to consider livestock food. Interest in specially bred guard dogs is growing. Flashing lights and noisemakers can also work as deterrents, though only temporarily.

One highly efficient means of wolf control was invented eons ago. It is the animals' own territorial system, outlined through frequent patrols and scent marking—chemical flagging. "See if you can pick out the musky odor," Scott Lindsay said, inviting me to kneel beside him and nose around in snow soaked with fresh wolf urine. "It's stronger than a dog's." The scent reminded me of sour woodsmoke.

A former high school science teacher, Lindsay was volunteering on a federal research project in Minnesota's Superior National Forest. We had spent the afternoon skiing along the frozen Kawishiwi River to check on fresh deer kills. Mike Nelson, Lindsay's supervisor at the time and one of the country's leading authorities on deer, and David Mech, a federal wolf expert, have been documenting the relationship between these two species for three decades. Their data show deer numbers being affected chiefly by winter conditions—snow depth, cold, and available food—rarely wolves.

In small wolf packs, only the alpha male and female breed. Pup survival may increase as deer populations do, but once a pack begins to grow past a certain point, social tensions mount until members begin to disperse. Where the researchers kept a tally, the number of packs stabilized some 20 years ago in keeping with the number of available deer. The density of wolves has stayed at around one for every 10 to 15 square miles ever since, and it will probably remain the same, Mech said, until deer numbers drastically rise or fall.

A pack can't expand its territory without trespassing, inviting a fight in which members have a good chance of being injured or killed. In fact, Mech explained, the leading cause of death among wolves here is neighboring wolves. Yellowstone holds as many as 35,000 elk—way too many, some say, pointing to signs of range deterioration from overgrazing. Wolf proponents argued that reintroducing packs would help bring the herds into balance. Perhaps, yet the few dozen wolves currently in the thick of this bounty have already begun killing one another in conflicts over turf.

Even when spread out by their territorial system, wolves die of hunger, especially when young. Distemper, parvovirus, heartworms, and intestinal parasites claim others, hitting wolves hardest where they are most abundant. Lyme disease affects them. Mange, caused by

"The wolf is my helper spirit," says Bob Danielson, a member of the Ojibwa tribe who regularly dons a pelt at powwows like this one in northern Minnesota. "The wolf is cunning," he says with admiration, "and has been able to persevere after nearly being exterminated." Gathering strength in a Kansas zoo, a litter of Mexican wolves (below) boosts hopes of restoring this subspecies of the gray to New Mexico and Arizona.

**After decades of darkness, the wolf is back, but under circumstances that are hardly natural. For eons wolves survived because they were fierce competitors; today they live because we want them to. People now wield the power to say: Let there be wolves.**

scabies mites, is spreading among packs in the Lake Superior region; the condition can lead to hair loss and a slow death by freezing. Concerns that wolves will keep multiplying until they wipe out prey are misplaced. People have done that. Wolves seldom do.

On the other hand, the notion that wolves cull only old and sick animals doesn't hold up either. "Our data show that wolves take mainly the youngest deer—those less than a year of age," Nelson told me. "Old, weak animals are the second most common targets." Moreover, wolves do occasionally kill more than they can eat right away, most often when prey are floundering through deep snow. Though such surplus killing provides a pack with more meat to scavenge later on, their version of stocking the pantry still strikes us as wanton slaughter.

"Each wolf takes an average of 18 to 20 deer a year," Nelson continued. "The herds can handle it. Whitetails in good habitat are incredibly productive." With generally moderate winters prevailing from the 1970s until 1995, deer in Minnesota's wolf country tripled despite a rebounding wolf population. The depredation many farmers worry about these days is by whitetails, which have been pillaging oats and corn even as hunters and motorists kill about 200,000 deer every year.

THE NEXT TIME I ran into David Mech, he was standing atop a butte in Yellowstone with binoculars pressed to his eyes, breath geysering into the cold air. "This has become the best place in the world for observing wolves," he said. Mech would know. He has watched *Canis lupus* around the globe and recently started an intensive study in the park's northern range. Open grasslands streaked with sagebrush sweep between the mountainsides, and one can keep animals in sight for hours on end. Sunlight and fresh mountain winds strip away the shadows that always seem wrapped around the wolf of European and North Woods lore. What emerges is just a powerful predator playing its role within a varied community of other carnivores and hoofed prey, much as you might find on the plains of East Africa.

The wolf pack before us moved from one elk band to the next, taking their measure. Sometimes the elk outran the wolves. One bull elk whirled so fast on a pursuer that a loose antler flew right off his head. Others drew together and stood their ground, warding off incursions with violent kicks. As an elk foreleg could easily smash ribs or dent a skull, the wolves tried bluff rushes, looking to cause a band member to panic and bolt. We could sense a battle's momentum seesawing second by second, the outcome never preordained but rather a summation of each animal's skill, determination, and experience, plus a little old-fashioned

luck. One morning I watched an elk disappear over the brow of a ridge with a wolf hanging on each shoulder. Three minutes later it reappeared—seemingly uninjured—and was soon grazing while the wolf pair loped off.

More than a species is being restored. This is a reawakening of real natural history. As the foremost hunter of hoofed prey in the Northern Hemisphere, wolves had a huge say about which animals passed on their genes. In each generation the winners were those a shade stronger than average, more agile, a degree fleeter, maybe more communicative, better able to maintain an alert group. Over tens of thousands of years, trial by wolf forged the elk, deer, moose, caribou, bison, wild sheep, mountain goats, and musk oxen we admire today.

In a deeper sense the elk *is* the wolf, and the wolf *is* the elk, the demands of each have so strongly influenced the other's evolution. A mutual shaping process embraces the wolf and its competitors too. On the west side of Glacier Park, University of Montana researchers found grizzlies, cougars, and wolves taking a roughly equal toll of prey. Now that grizzlies have both wolf and cougar leftovers to scavenge, a few male bears stay active all winter rather than retreating to a den. From the huckleberry seeds spread in bear droppings to the grouse that prosper where wolves reduce coyotes, linkages lead in every direction. I begin to glimpse what the Nez Perce mean about Wolf making the circle whole again. □

For more on gray wolves join our online forum at www.nationalgeographic.com.

*Twirling to home-cooked Acadian fiddling, dancers take a party to the porch. In Canada's smallest province, islanders revel in their way of life. Its pace is sure to change with a bridge to the mainland now open.*

## Prince Edward Island

# A World Apart No More

By IAN DARRAGH

Photographs by SUSIE POST


Budweiser
Budweiser

"TO CATCH LOBSTERS, you have to think like one," says Allan MacDonald, who has been setting traps off Prince Edward Island for more than five decades. From his dad he had learned where the lobsters migrate and when, but he wasn't revealing any secrets to someone "from away," like me.

With his son, Charles, his daughter-in-law, Shelly, and their golden retriever, Duke, we had set out at 5 a.m. under a full moon from the island's south shore, red harbor lights shimmering in our wake. Also on board is Steve Ryan, a biology technician who is surveying the lobster catch as part of a study of the environmental effects of Confederation Bridge. The eight-mile-long ribbon of concrete, which opened in June 1997, connects Prince Edward Island, Canada's smallest province, to the mainland for the first time in 5,000 years. But it also cuts right through MacDonald's lobstering grounds in Northumberland Strait.

For five hours we've been hauling up lobster

traps within sight of the bridge, which looks like a Roman aqueduct, its rounded arches disappearing into the fog. Every trap Charles hauls up on the hydraulic winch is coated with rock crabs, which scuttle off sideways across the deck. Steve measures each lobster with a pair of calipers and throws back females whose undersides are "berried" with black eggs.

MacDonald has been a vocal opponent of the bridge, arguing that a tunnel would have been less risky to the fishing industry, which brings in 70 million dollars (U.S.) a year,

*Clouds cast an illusion of pastoral isolation over potato and dairy farms at Malpeque Bay on Prince Edward Island's north shore. Before the bridge across Northumberland Strait, ferries—and modern electronics—were the island's primary links to the world. "Farmers use cell phones, e-mail, and faxes to market their products," says author Ian Darragh. "The Internet is big here."*


*Forced off their land by the British in the 18th century, native Micmac suffered hardships as white settlers took over. Today some 940 Micmac survive on and off the island's four reservations. In 1758 a handful of French-speaking Acadians hid to avoid expulsion by British forces. Pockets of their descendants live on the western half of the island.*

making it the island's third most lucrative industry, after agriculture and tourism. After a three-year ban on fishing in the construction zone around the bridge, MacDonald and others have been setting traps in its shadow—with rewarding results. Prices are high, and so far lobsters are plentiful. Dredging for bridge construction created ideal habitat for shellfish: Each of the 44 main pillars sits in a large, steep depression pitted with cavities, where lobsters and crabs have taken up residence.

Nevertheless MacDonald is dubious. "Here in the strait the lobster population goes in cycles. We've had ups and downs in my lifetime and in my father's before me." It's too early to tell, MacDonald says, what, if any, effect the bridge will have on his livelihood.

While people debate how the bridge may alter the environment of Northumberland Strait—from the swirl of the currents to the spring breakup of ice—it is already changing the ebb and flow of life on the island itself, a place long defined by close-knit communities and a slow-paced way of life.

Prince Edward Island (P.E.I. for short) has only 137,000 year-round residents, but 740,000 tourists came over by ferry or plane in 1996. In 1997 the number swelled to 1.2 million—a direct consequence of the bridge, which can carry up to 4,000 vehicles an hour. Few dispute the convenience of driving off the island in 12 minutes instead of enduring summer waits of two or three hours for a 45-minute ferry trip. But many islanders worry that the bridge will bring crime and increase the pressure to build resorts along the unspoiled shoreline.

On P.E.I. change has often come slowly. Some parts of the island got paved roads and "the lights," as electricity was called, only in the early sixties. The 1970s finally saw the demise of the one-room schoolhouse, and even more recently small family farms have given way to agribusinesses—operations of up to 3,000 acres that grow potatoes to feed the North American appetite for french fries. How islanders come to accept this newest—and potentially most far-reaching—form of change remains to be seen.

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Canadian IAN DARRAGH says that while researching this article, his second for the magazine, he learned how to band a lobster without losing any fingers. SUSIE POST, a freelance photographer, specializes in documenting the lives of people; her first article for the GEOGRAPHIC was "The Aran Islands" (April 1996).

TO THE OUTSIDE WORLD Prince Edward Island seems a bucolic paradise. The first thing you notice is the red earth, and as you drive around the countryside in summer, you see potato vines blooming in white or purple, and tidy fields of golden grain and green clover stippled with bronze bales of hay. Around every corner, it seems, you glimpse the sea, with whitecaps dancing on the waves. Then you come to a village, with a shingled neo-Gothic church and a main street lined with trim wood-frame houses painted in yellows, greens, and reds.

"The words I associate with the island are intimate, compact, and pastoral," says Heath Macquarrie. Still fit at the age of 78, Macquarrie represented P.E.I. as a member of Parliament and a senator for 37 years, after starting out as a teacher. His white hair and sideburns frame a ruddy face that quickly dissolves into a broad grin. "In summer I go swimming at the beach here in Victoria, and every day someone walks by who I've known for 40 years or more. You know your neighbors so well that you can help them out without offending their pride."

When someone dies on P.E.I., the family is inundated with casseroles and offers of help. Islanders are so tightly knit, in fact, that a local historian once quipped: "Everyone feels he has the divine right to know exactly what his neighbor is not only doing but thinking!"

"The dark side of the sense of community is the lack of privacy, the lack of freedom to speak your mind," says David Weale, a silver-haired professor of history and native studies at the University of Prince Edward Island. Weale spoke out against the bridge and was criticized for it. He says that many prominent people—doctors and lawyers, for example—were afraid to take a stand one way or the other for fear of losing clients. "You can't openly offend anyone, because you're going to see them the next day—and for the rest of your life."

But, Weale adds, "We islanders still know who we are and where we belong. Like the woman who was asked if she had traveled much. 'No,' she said thoughtfully. 'Didn't have to. I was born here!' "


*Too young to toe-tap on her own, Bronwyn Spenceley gets a leg up from mom at a jazz festival in Charlottetown. The capital and main city is a cultural hub for the island's 137,000 residents. Since the bridge opened last June, a million tourists have crowded the city's streets.*

*"You look out on a patchwork quilt of color, and it hits you: A viewgasm!" says local playwright Nils Ling. A falling tide on the south shore uncovers sand tinted red by iron oxide, a quiet place for an islander to walk his dog.*

*Image is everything at a Japanese couple's marriage, made legal later in Japan. The wedding mimics the 1911 nuptials of Lucy Maud Montgomery, author of the* Anne of Green Gables *series, so beloved in Japan that couples flock to the island just for such re-creations.*

OVER THE CENTURIES "The Island," as most people call it, has gone by a variety of names. In 1758 the British claimed one of the jewels of France's New World empire, later naming it after Prince Edward, the father of Queen Victoria. To the Micmac Indians, whose roots go back at least 2,000 years, it is Epekwitk (or Abegweit).

White settlers tried to push the Micmac off the island, clearing the land and exterminating the walrus, caribou, and bear the Indians depended on for food and clothing. Until 1970 most Micmac youngsters were sent away to residential schools and forbidden to speak their native tongue. Today fewer than 5 percent of Micmac, mainly elders, still speak their flowing, musical language. Healing sweat lodge ceremonies were also banned.

John Joe Sark, the first Micmac to graduate from the University of P.E.I., in 1979, calls it "a calculated case of cultural genocide." On the Lennox Island Reserve, one of four small areas set aside for the Micmac, I met Tommy Sark, 57, a distant cousin of John Joe's. Tommy, one of the last traditional artisans, makes elegant baskets of white ash. He was sent to a Roman Catholic residential school in Nova Scotia at the age of five, not knowing a word of English. His native name, Dummage, was changed to Tommy, and he was beaten by the nuns every time he spoke Micmac.

"Residential schooling wasn't exclusive to P.E.I.," says David Weale. "It was a national policy to efface as much native culture as possible in the belief that this would enable Indians to fit into mainstream society."

The Canadian government now admits this program had the opposite effect, banishing them to the margins of society. Forty percent of Micmac are unemployed or on welfare, including John Joe Sark, who lost his job as an economic development officer for the provincial government in 1994 due to downsizing.

What of the future? "I don't think the bridge will make any difference for my people," John Joe says, because few Micmac work in tourism. "To get the confidence we need to improve our lives, we have to develop pride in ourselves by discovering who we are and who we were."

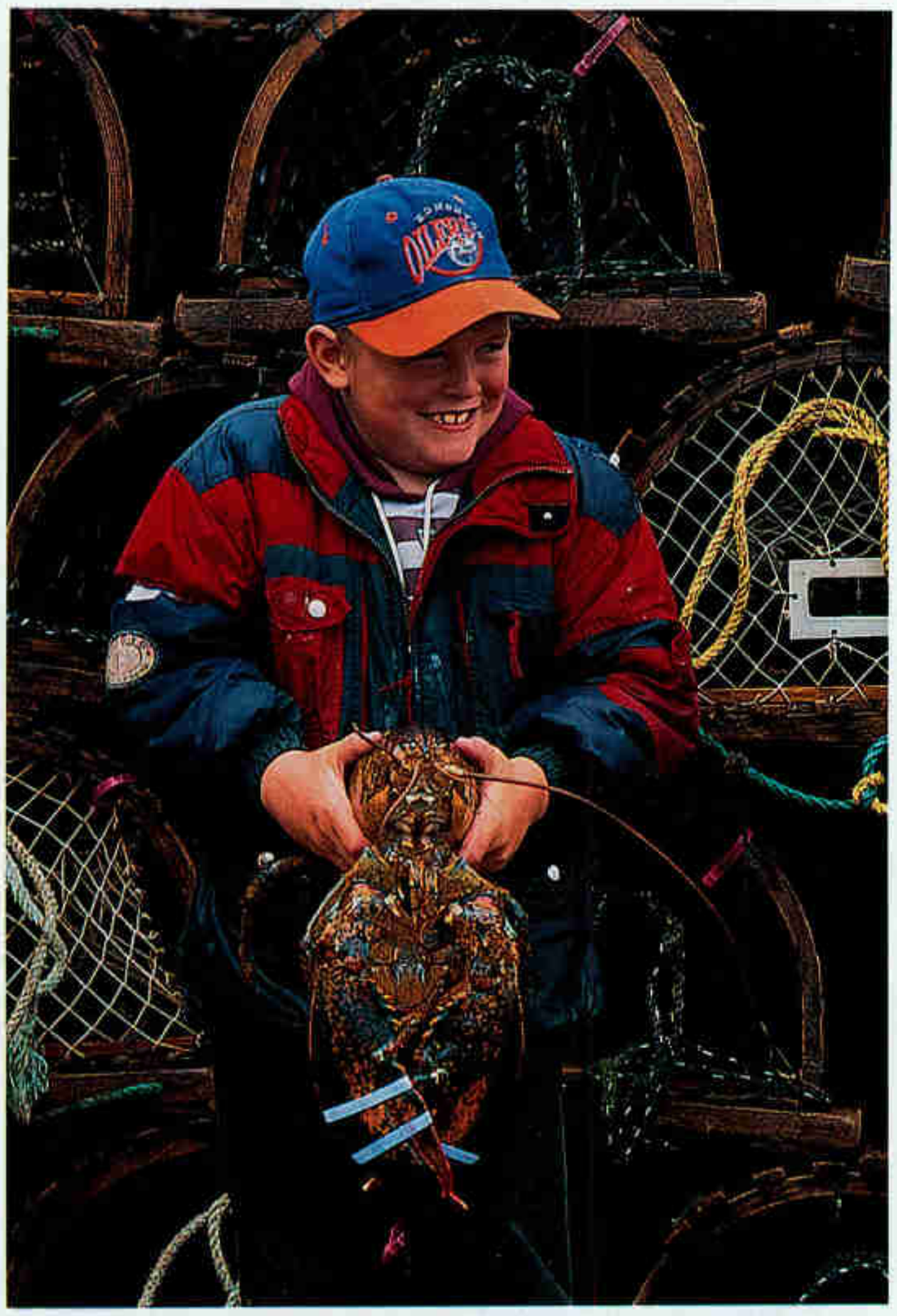
To raise the visibility of his people, John Joe is writing a history of the Micmac, organizing exhibits, and reviving the sweat lodge ceremony, for which he gathers medicinal plants and tree bark and boughs. He goes to the wooded hills of the island's central dome to collect boughs of Canada yew on 55 acres owned by his friends Malcolm and Christine Stanley. A fern-lined path under a shimmering green canopy of sugar maples and birches leads

to the Stanleys' front gate. Mounted on it is a clay sculpture of a man with bushy eyebrows and mustache, sticking out his tongue.

MALCOLM, 42, is a sculptor and potter with a puckish sense of humor. He has a flame-red beard and wears his long hair in a neat ponytail. Christine, an expert carpenter, built their rambling, cedar-shingled house with the help of friends and neighbors. As we drink coffee in their luxuriant garden, ruby-throated hummingbirds dive-bomb the scarlet runner beans blooming on the trellis, and their two enormous, woolly Newfoundland dogs try to snitch cinnamon rolls from the table.

The couple were part of the back-to-the-land movement that began in the late 1960s and brought more than a thousand young people to the island from all over North America. "We wanted a place with lots of room where we could raise our children and keep animals," Christine tells me. "And P.E.I. has a reputation as a good place for craftspeople."

With their tie-dyed shirts, beads, and long hair, these newcomers stood out in P.E.I.'s conservative rural communities, and they had an influence far greater than their numbers. Some became journalists and environmental activists, while others, such as the Stanleys, flourished as artists and musicians, adding a new cultural dimension to island life.




*"Banding lobsters is the best," says seven-year-old Jonathan Paynter. "The worst is getting bit." His catch of the day, at six pounds, is a small part of the island's 50-million-dollar (U.S.) lobster industry. Potatoes take the lead in agriculture. At harvest's end Kenny Waugh, at right, and Cory Gordon enjoy a break on a day that worked them into the night.*

Like many of their neighbors, including a violin maker and a tinsmith, the Stanleys don't lock their doors. "One time Malcolm put the 'Back in Ten Minutes' sign up at the pottery studio," recalls Christine, "but when he got to the house, the goats had all escaped. By the time he rounded them up and had some lunch, there was a group of Texans sitting around the porch at the studio. They kept saying, 'Where can we sign up for this lifestyle?'"

I saw the same trusting attitude at the fruit and vegetable stands along the island's twisting roads. Prices are marked on a board, and you leave your money or take change from an unlocked box. Many islanders I met, the Stanleys among them, wonder whether self-serve stands and unlocked doors will become a thing of the past as increased traffic over the bridge depersonalizes P.E.I. But the Stanleys aren't going to change their ways. "None of our locks have worked for years, and I'm not going to get them replaced now," says Christine. "If we get robbed, our attitude is that anyone who wants something that desperately can have it."

As with any megaproject, Confederation Bridge has its champions as well as critics. For Pat Binns, Prince Edward Island's 50-year-old premier, it represents a tremendous opportunity. "It's going to make our exports cheaper and bring economic development," he says,

predicting that the new accessibility will attract food-processing and high-tech companies.

But Heath Macquarrie, the retired senator, says the bridge may make it more economical for companies to centralize their operations on the mainland. A plant producing frozen french fries, for example, could truck potatoes directly to New Brunswick for processing, thus avoiding the need to operate a separate plant on the island, where land is more expensive.

The bridge is a boon for island exporters, such as Blair Horne, a third-generation potato farmer. His thousand-acre operation grows seed potatoes, which are sold to farmers for planting.

"Competition in the potato industry is fierce," says Blair, who exports his crop as far away as Florida. "You're up against every other grower in North America, and we need every edge we can get. With the ferry we had trucks idling for hours on the dockside, and there were days in winter when the boats weren't running because the ice was bad. Now we can get our product to our customers faster, and we can guarantee when it will be delivered."

Judging by the sharp increase in the number of visitors to P.E.I. after the bridge opened, tourism is another sure gainer. "If it's handled properly, tourism can be a wonderful resource," says David Weale, the history professor. "If it's not, it can be the death of the community. Assessing the latest fad and then

*An open road to development, the eight-mile Confederation Bridge linking P.E.I. to New Brunswick—shown nearing completion—shut down a fleet of ferries. Trucks move products quicker, boosting the economy. But islanders fear outsiders will spoil their solitude.*


gussying ourselves up to meet it is really a form of prostitution. And we've done a fair bit of that, with theme parks featuring King Tut's tomb and the space shuttle. What do they have to do with P.E.I.? We've destroyed dozens of vistas on the north shore, and if you fast-forward this trend, I think much of the charm could be eroded."

It's hard to imagine anything undermining the sites associated with the *Anne of Green Gables* books, written by Lucy Maud Montgomery. These Canadian classics, which draw hundreds of thousands of tourists to the north shore every year, tell the story of a spunky red-haired orphan named Anne Shirley, who comes to P.E.I. when she is adopted by an elderly man and his sister. They had requested a boy to help with the farm chores, so when Anne arrives, she is at first unexpected and unwanted.

Anne's most enthusiastic fans are the 12,000 Japanese, mainly women, who visit P.E.I. every year. The novels are studied in Japanese schools and have attained cult status there because of their portrayal of the island as a rural paradise.

"Happy, happy, I'm so very happy," says Yoshiko Aono, who has traveled halfway around the world from Yokohama, Japan. "For 30 years I dreamed of coming here. It's so green, so peaceful."

Why the fascination with "Anne of Red Hair," as she is known in Japan? "Anne is the girl I wanted to be when I was growing up," Mrs. Aono says. While the novels are often seen as sentimental children's literature, they have strong feminist themes, and Japanese girls and women admire Anne's plucky spirit.

In a minibus with Mrs. Aono, her husband, and 20 other Japanese visitors, mainly women, I spend a day visiting New London, where Lucy Maud Montgomery was born in 1874, the farmhouse at Park Corner where she was married, and her grave in Cavendish. This garish town is the epicenter of Anne memorabilia, and every other store is named after Marilla, Matthew, or another character from the novels.

Our driver tells me that he brought us here

*Taking a plunge with his pals, 12-year-old Kris Locke (left, second from right) tests the water at the harbor in Victoria. "Summer's the best time of year on P.E.I.," he says. "The water's great, you can skateboard, and there's no school." In winter, when not taking his grandsons to hockey games, Dale Marchbank packs his lunch and heads for the ice to spear smelt in a hole under his buddies' homemade shack. "The stove keeps it nice and warm," he says. "No point going down there to freeze."*

from Charlottetown, the capital, by a route chosen to avoid as much unsightly strip development as possible. The goal: a rural image of P.E.I. for Japanese visitors.

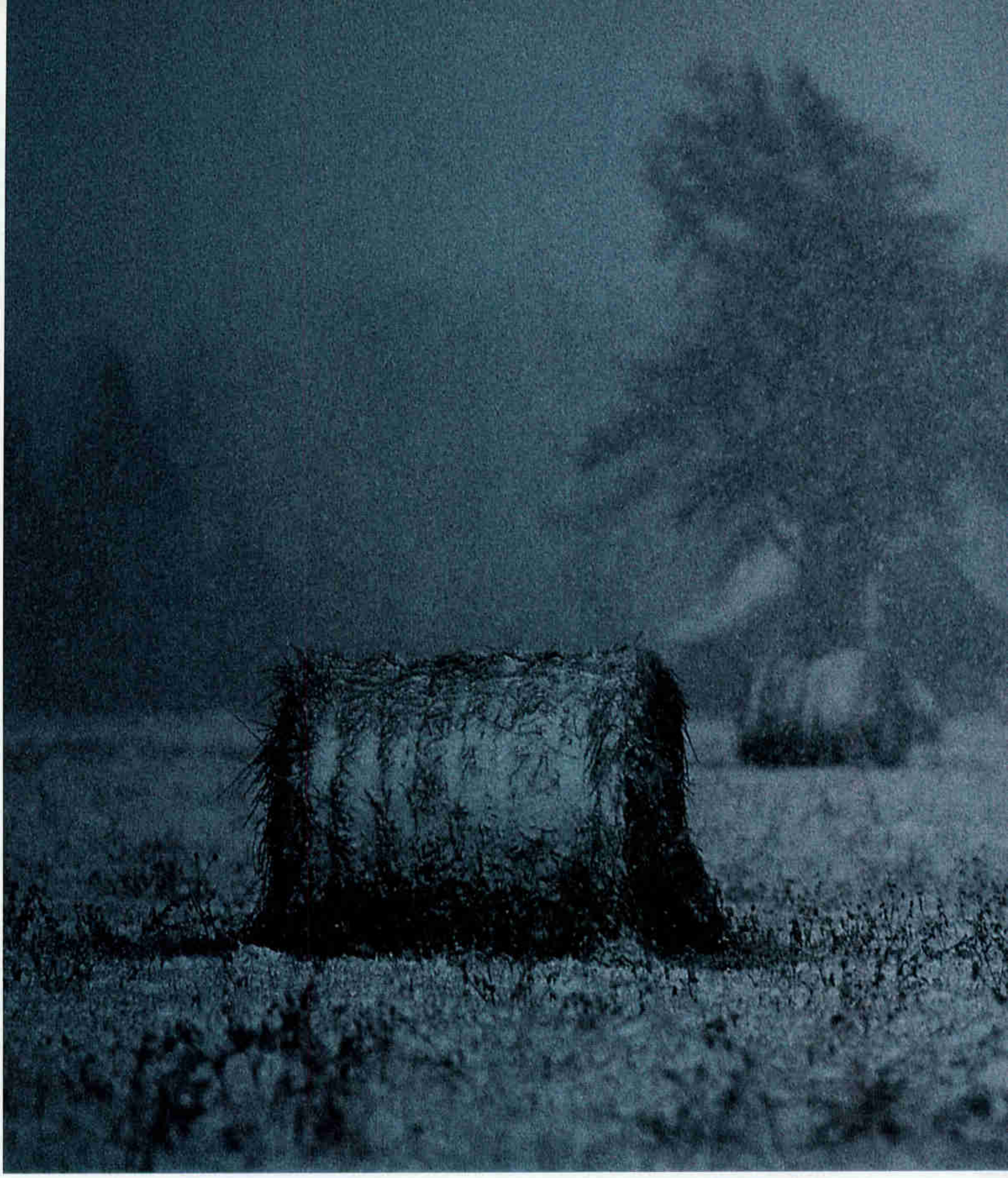
PAT BINNS, the island's premier, acknowledges the risks of dressing up P.E.I. His government plans to introduce stricter zoning laws to prevent the spread of what he calls "Coney Island development." Binns wants to encourage sea kayaking, bird-watching, and other types of ecotourism activities that local outfitters are now beginning to offer. "The challenge," he says, "is to preserve the best of what we have."

For 30 years Ian MacQuarrie, a biologist and one of the founders of the Island Nature Trust, has been fighting to keep commercial activity off the Greenwich Dunes on the northeastern coast. In addition to extensive sand dunes, the thousand-acre site protects a diversity of habitats, including boggy areas with rare orchids and a secluded beach where the piping plover, a threatened bird, nests. The trust has staved off plans to build condominiums, a golf course, and a marina on the peninsula, which is now slated to become part of P.E.I. National Park, the only one on the island.

Ian and his wife, Kate, the executive director of the trust, invite me to hike into the dunes. Ian points out how the sand hills have engulfed a spruce forest and killed the trees. "All it takes is one good storm. It's amazing how things can shift." As the dunes move, they leave behind crescent-shaped relict ridges—the only known example of this landform in North America.

At the beach—so dazzling in the August sunlight that I have to squint—a few couples are lounging under umbrellas, their kids collecting shells or leaping over the waves. After walking a hundred yards around a point, we are alone, except for a pair of great blue herons fishing along the shore, as still as driftwood. "The way to appreciate a place like this is to sit and soak it up for a few hours," Ian says.

Kate spots an osprey carrying a wiggling fish in its talons. Then two bald eagles fly over us, a species the MacQuarries now see more



*Vacant but not abandoned, a 150-year-old farmhouse is still owned by descendants of the family who built it. Generations of Scottish McDonalds lived within those walls, sharing good times and bad with their neighbors. "If you grow up here, you take the island deep inside," says P.E.I. historian David Weale. As Prince Edward Island faces change, islanders hold fast to their sense of closeness and community.*

often. Since DDT was banned in the U.S. and Canada, the raptors have slowly been making a comeback on the island, and 35 chicks have been banded in an adopt-an-eagle program.

We stop in a meadow where a developer, George Diercks of Long Island, New York, had planned to build a resort. Instead, after a land-use hearing, he agreed to swap the dunes site for 500 acres of abandoned farmland nearby, where he plans to build a hotel and golf course.

"This way everyone wins," Diercks later

explained. "The dunes and Paleo-Indian artifacts on the site will be protected, and there will be an interpretation center for visitors."

On the way back to the parking lot we meet Lynn and Phil Brown, from Tunbridge, Vermont. "This is a jewel of a place," says Phil, a physician. "I can't remember ever seeing so many shorebirds. And there are miles and miles of beaches with no rubbish on them. There's an opportunity to avoid doing what other coastal areas have done. On P.E.I. the beaches are still accessible. In New Hampshire, where I spent summers as a boy, most of the coast is cut off from the public."

For four summers the Browns have traveled to P.E.I. by ferry. This year, however, they came over Northumberland Strait on the bridge. "It was weird," says Lynn, a teacher. "You no longer feel like you're crossing over to an island. Now it's like driving any highway—you just zip along, and you're here. I hope it doesn't take the mystique away."

The Browns are coming back next summer to find out. □

Plunging into 30-foot seas and a howling gale, *EF Language* charges through the southern Indian Ocean's treacherous roaring forties. The 4,600-nautical-mile South Africa to Australia passage is one of the toughest legs of a round-the-world race that batters boats and sailors.

# The Whitbread—

# Race Into Danger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VINCENT J. MUSI

**STIFF BREEZE** and a fair sky make for a picture-perfect start (above). *EF Language,* sponsored by an international language-education company, jumps in front as the fleet sets out from Southampton, England. All entrants are Whitbread 60s, a class of ultrafast sloops named for the race's original sponsor, a British company, and the boats' length in feet at the waterline. After winning the first, and longest, leg, *EF Language* leaves Cape Town, South Africa, outbound for Australia (left).

By ANGUS PHILLIPS
Photographs by RICK TOMLINSON

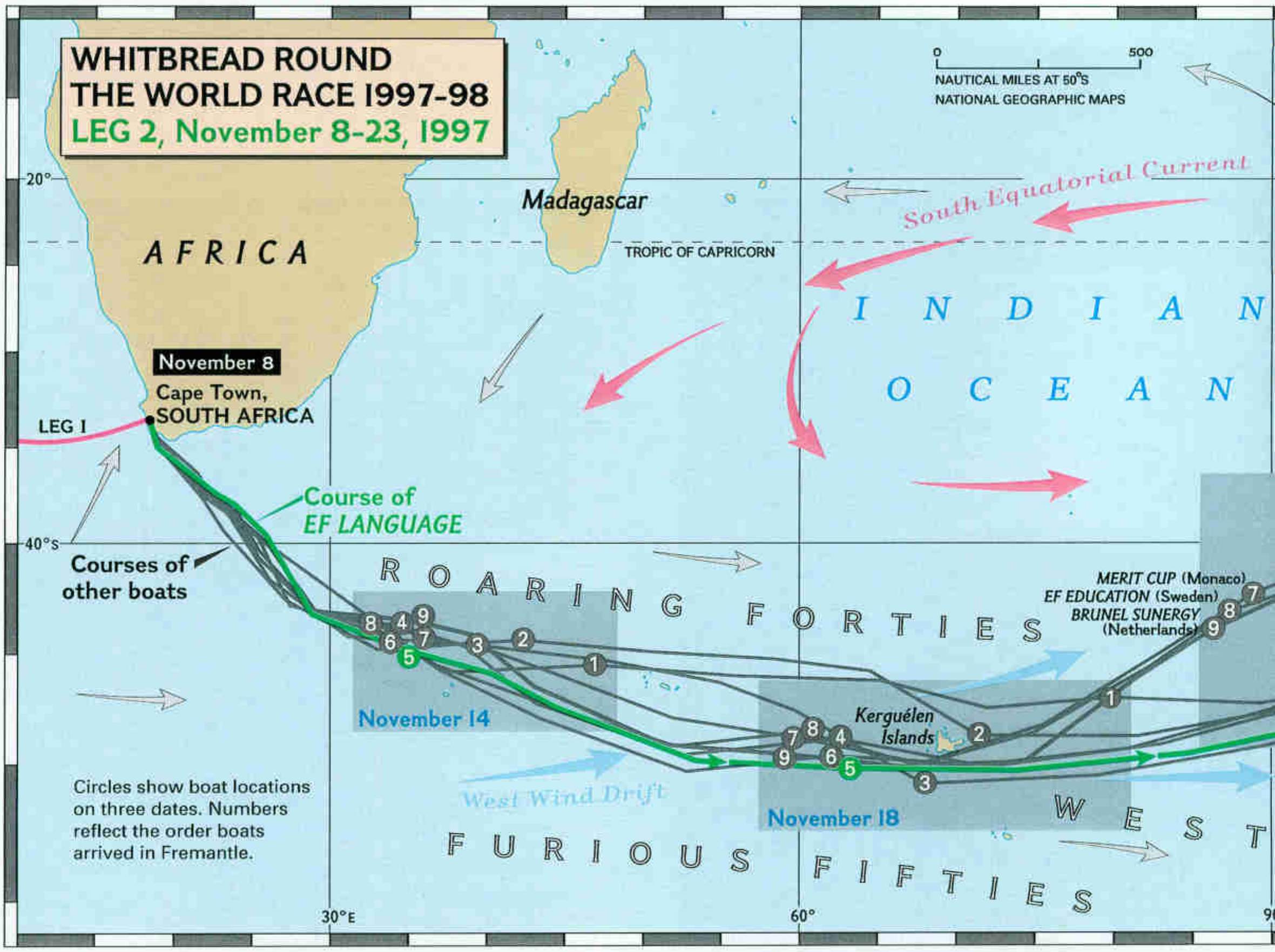
THE INDIAN OCEAN is a vast, empty place. Somewhere out here in the cobalt blue water a hundred nautical miles offshore, the racing sailboat *EF Language* is charging toward us, up from the Southern Ocean, bound for Fremantle, Western Australia, and the finish of the second of nine legs of the 1997-98 Whitbread Round the World Race. But where?

Three of us on the steel ketch *Jodi Anne* scan the dawn sky for a sign, but all we can see are ocean swells, whitecaps, clouds, and a few seabirds nipping at the wave tops. Then, far off to the southwest, a small, dark, angular line pierces the horizon.

We board *Jodi Anne*'s rigid-bottom inflatable and fire up the outboards. The waves look huge from the tiny boat, and in the troughs our target sometimes disappears. But on it comes, sails cleaving the sky in tomahawk chops until at last we make out the bodies, then the faces, then the smiles through the whiskers of the weary seamen. We speed in under the stern quarter, throw over my seabag, and the blue-clad lads on *EF Language* haul me up by the seat of my oilskins.

"Welcome," says watch captain Kimo Worthington, extending an oak-hard hand, fingertips blackened by frostbite, "though I can't imagine why you'd even want to come aboard. Everything's broken, everybody's hurt, we stink, the boat stinks, we haven't been out of our foul-weather gear for 16 days."

As I survey the wreckage—broken steering wheel, patched sails, ruined winches, life rails ripped away by boarding seas—and whiff the stench from the living quarters below, which reek like a gym bag left to fester, I can see it's been a harrowing 4,600 miles since the start in Cape Town, South Africa. For eight of the twelve men aboard, including Paul Cayard, the skipper, the run east has been their first encounter with the ocean latitudes known as the roaring forties and furious fifties, where




gales blow year-round and seas build to towering peaks, the "liquid Himalaya," as one Kiwi broadcaster calls them.

"Climbers do Everest, divers do the deep sea, and sailors do the Whitbread," says Cayard, who, at 38, is by all measures among the best competitive sailors in the world.

So confident is he of his skills that he sometimes speaks of himself in the third person, as if he were an institution rather than a mere human. At this point in his career, he says, "the Whitbread is a good thing for Paul Cayard to be doing."

Every four years since 1973, when Whitbread, a British company, sponsored the first race, boats have circled the globe, starting in England in the fall and returning six or more months later. This year, for the first time, all the boats were of the same class, 64-foot, high-tech sloops with water ballast systems to help keep them flat and fast in the strongest winds. Global corporations sponsor these vessels at a cost of millions of dollars for the exposure. Some sailors earn $12,000 a month. Skippers can earn much more.

The heart of the race always has been two isolated legs through what many call the Southern Ocean, a frigid, spume-strewed ring of gale-force terror around the South Pole, where four Whitbread sailors have perished. Steering as far south as ever they dare, boats dodge whales and icebergs just as clipper ships did more than a century ago.

"It's the reason why we do the race," veteran helmsman Magnus Olsson says of the Southern Ocean. "The new guys all ask me what it's like. I can only say, you have to see it for yourself. But I will tell you this: It's scary to have a 30-foot wave chasing you. If you're steering, you don't look back. The crew looks back for you, and you watch their faces. When they look straight up, get ready."

I was aboard for a few hours at the start in Cape Town when *EF Language*, sponsored by a global language-training and cultural

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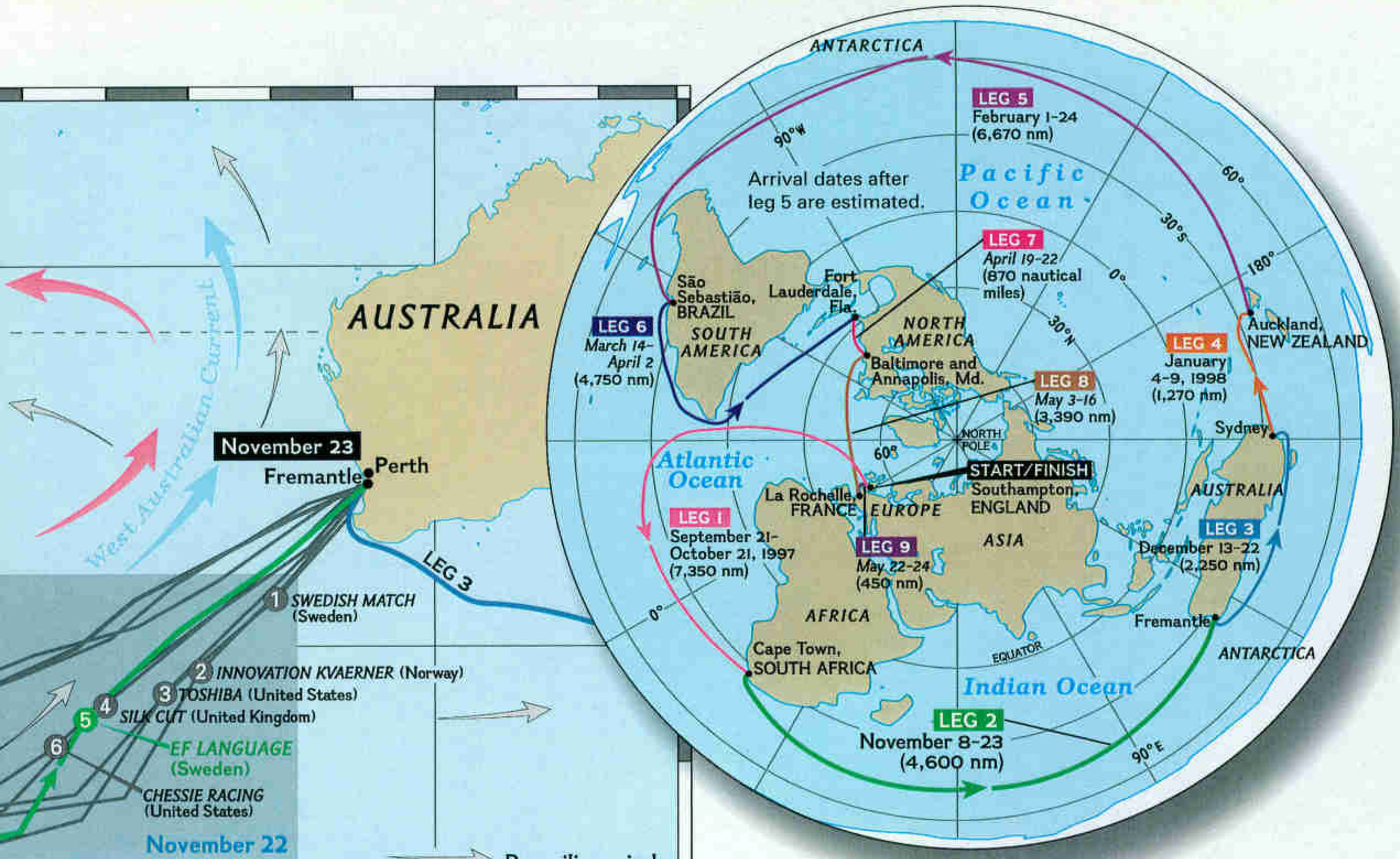
ANGUS PHILLIPS, Outdoor Editor at the *Washington Post*, races a 27-foot Soling near his home on the Chesapeake Bay. This is the fourth Whitbread Race for RICK TOMLINSON, who specializes in yachting photography.




# A Global Sprint

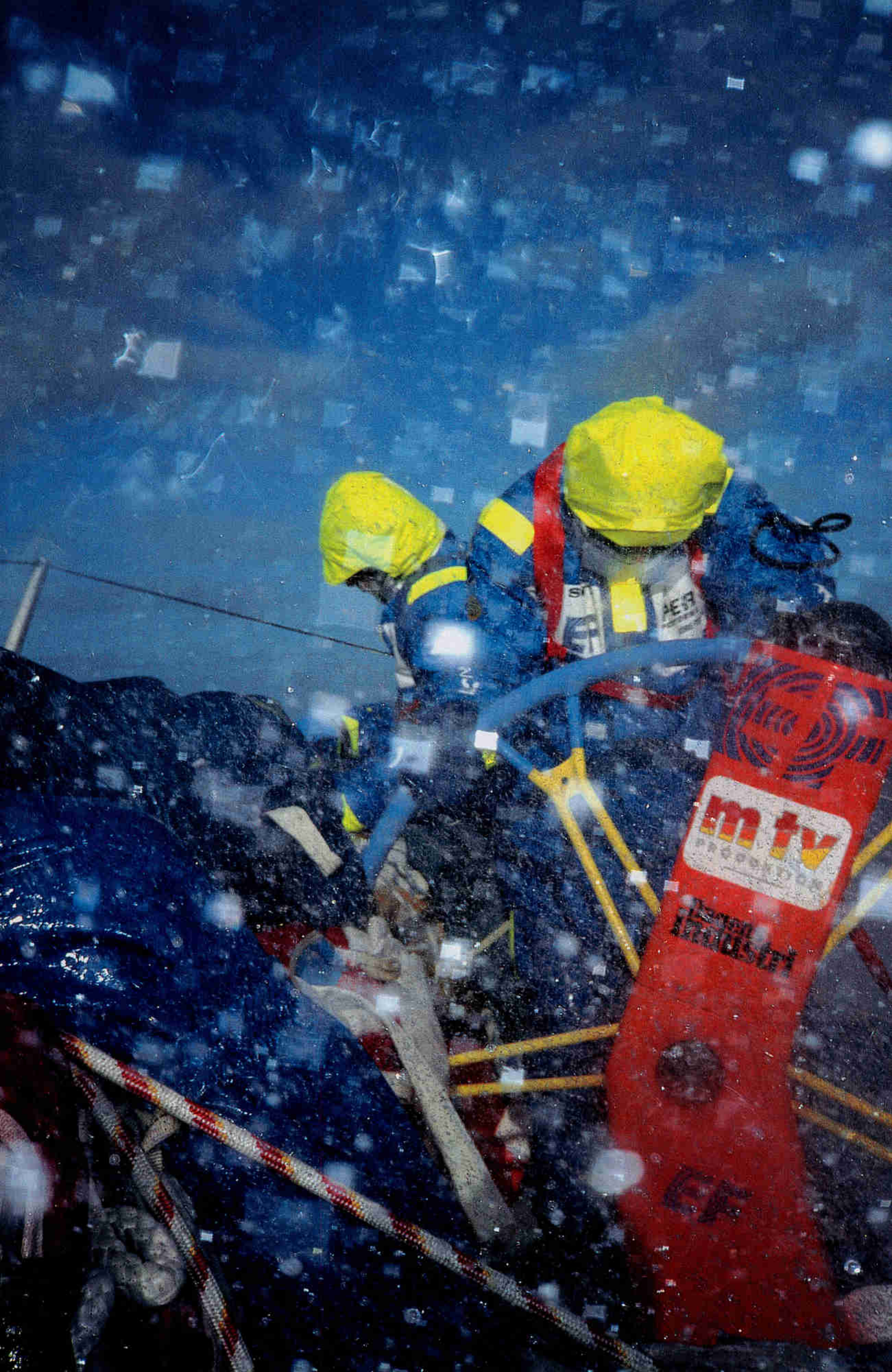
On the second of the competition's nine legs boats swing south to catch high winds but pay a price in numbing cold and notoriously rough seas. To make this round-the-world circuit, boats travel 31,600 miles in about eight months, including maintenance stops between legs. This is the seventh Whitbread, which has been held every four years since 1973.

Studying satellite imagery of weather patterns, *EF Language* navigator Mark Rudiger devises racing strategy and keeps track of the other boats. He is one of 12 crew members, the maximum number allowed.

education company based in Sweden, looked fresh and the crew was primed for adventures ahead. Cayard, a first-time Whitbread skipper, and his navigator, Mark Rudiger, who used to race around on motorcycles before shifting to offshore sailing, had steered the boat to a surprise victory over nine other entries in the 7,350-mile first leg from England to South Africa, finishing 160 miles ahead of the nearest rival. Spirits were high.

Instead of forging ahead into hoped-for raging gales beyond Cape Town, however, *EF Language* sailed straight into calms. For days the crew patiently worked sails in and out, trying to coax progress from the faintest puffs of breeze in a regimen of five-man watches, four hours on, four hours off. At the end of a week, the boat had slid to eighth place, then battled back to fifth in fluky breezes.

"It's a balmy New England day in the Southern Ocean," Kimo Worthington grumbled into a minicassette tape recorder kept by his bunk. Meantime, rival boat *Swedish Match* rode the breeze it had locked into on the first day and stretched to a commanding lead.


mtv

**STINGING CONFETTI** of icy droplets assails helmsman Steve Erickson (left). Whitbread 60s are equipped with special pumps and ballast tanks. Since a boat leans to leeward (away from the wind), water is pumped to the windward side to counterbalance the tilt, improving stability and speed. Under sail 24 hours a day, *EF Language* presses on as dawn breaks (below).

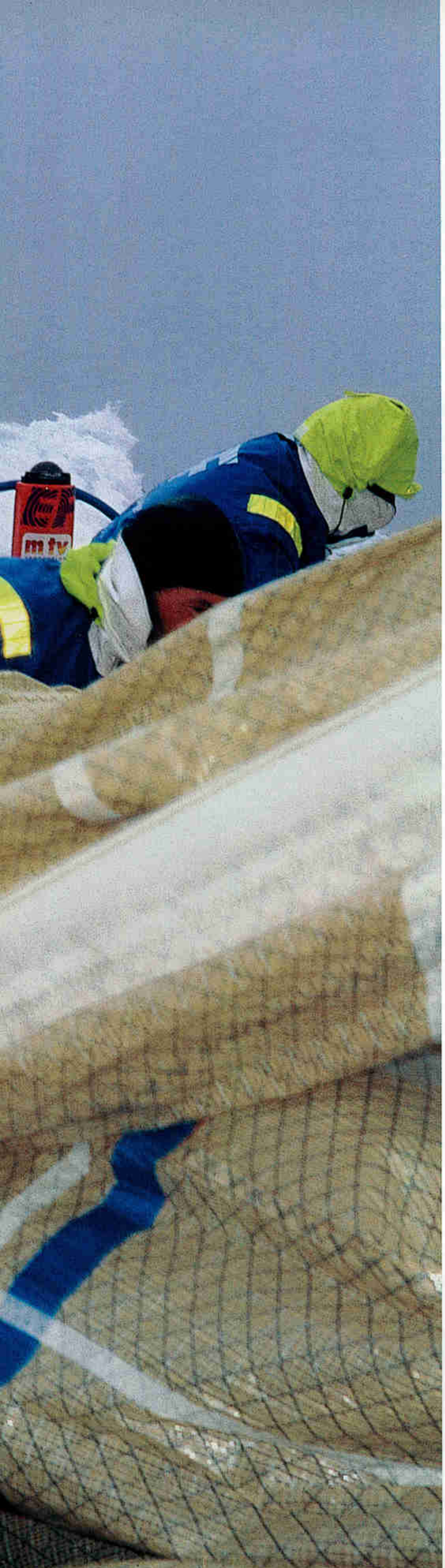

"We're 700 miles behind *Swedish Match;* they're going 15 knots and we're doing 9," Worthington lamented.

It was his last such gripe. Next night *EF Language* was up on its toes, and the icy ordeal was on. Speeding along at 22 knots (25 miles per hour) in its first real Southern Ocean buster, the boat was bounding toward the snowcapped Kerguélen Islands in the middle of the leg with a full mainsail and ballooning spinnaker stretched taut by a dense, damp 30-knot wind. Sheets of spray sluiced off the hull sides, blasting the crew like a fire hose. In such conditions, sometimes all the helmsman could see through his ski goggles was the compass a forearm's length from his face. "You get completely disoriented in the spray," said bowman Justin "Juggy" Clougher, a Tasmanian who pilots helicopters when he isn't racing boats. "It's like flying a helicopter in the fog."

Built for surpassing speed, Whitbread boats all but fly down the face of breaking waves, like a coin skipping across the water. The 5,650 pounds of water ballast that they can carry on the windward side to help stay level allows the crew to pile on heroic measures of sail. But in big seas that can be dangerous, as the vessel roars down waves so fast it plows into the next one ahead.

Suddenly *EF Language*'s bow did just that, digging hard into a foam-topped wave and sending a wall of green water racing down the deck. The wave smashed into a pile of spare sails stacked along the windward rail to help balance the boat. In the coal black night all was chaos. The water sent the spare sails flying over the side in their bags and knocked down the portside lifelines and stanchions—the "fence" that keeps crewmen and gear safely aboard. With nothing to restrain them, the sails washed along in the rushing sea, tethered only by straps tied to pad eyes in the deck. To lose them was to end all chance of catching *Swedish Match*—or anyone else.

"All hands!" shouted the five-man deck crew, summoning their sleeping mates topside. Cayard bolted from his bunk below, rushed for his foul-weather gear and safety harness, and scrambled up the dark companionway through the main hatch to a scene beyond his wildest imagining: Sails hanging overboard by their ties, unidentifiable bodies running around trying to lift the sails back on board, the sea whooshing by at 24 knots. To




Cayard the boat had become "a bull trying to throw its rider off."

It took an hour to get the waterlogged sails aboard, crewmen painstakingly hauling them in, inch by inch, with frozen hands and no lifelines for protection, minds numb to the danger as the sea raced by inches away. One sail was lost, but the others were salvaged.

It was a close call for *EF Language.* But Cayard, a strapping, mustachioed, six-foot-three native of San Francisco, is famous for pushing his luck to the edge. With four America's Cups and a Star-class world championship behind him, the only way for him to go is all out, at the margin of control, where things are on the verge of breaking. "I've won America's Cup races by one second. That's where I come from, feet and inches, seconds. In that environment you don't give up anything to anyone," he says.

The Southern Ocean, however, is an unforgiving place. Not since the 1850s, when the Australian gold rush began, have fleets of vessels sped headlong around the tip of Africa, bound for the antipodes and determined to get there first. Those were days of pitiless seas and iron sailors, most notably one James (Bully) Forbes, who was said to command the men on his clipper ships with a pair of leveled revolvers. After the Suez Canal opened in 1869, offering a warmwater route east, and steam power gained a foothold in seagoing commerce, the Southern Ocean languished largely unused until modern times, when yacht racers saw in it a challenge.

It's still the shortest route from the tip of Africa to Australia, unimpeded by land, and the wind almost always blows hard from some quadrant of the west as low-pressure storm cells sweep around the planet, sending eastbound sailboats scudding ahead on harsh but favorable breezes. Whitbread boats get faster and scarier all the time, these days whisking along at 30 knots or more.

By the tenth day of the race, worn down by extreme conditions, the crew started to make mistakes. One sailor fell asleep and let go of

**FLAT OUT FAST.** Their slickers bearing reflective safety strips, crewmen haul in a foresail as they adapt to changing wind and weather. A boat may carry 17 sails. Which ones to set for maximum speed and safety is a constant, critical choice for the skipper.

the line controlling the spinnaker, which smoked off its winch and went flying over the side as the big sail flailed wildly. Had anyone been caught in the line, he could have lost a limb or even his life. Another helmsman lost control of the wheel in a gust, *EF Language* rounded into the wind, and the spinnaker flogged itself to shreds.

Struggling to keep up with repairs, Marco Constant, the sailmaker, stayed below on the cabin floor with his sewing machine, patching ruined sails for four straight days. The boat was a dark-brown cave down there, the Kevlar inner skin unpainted to save weight, cold condensation dripping off the hull sides. The drying heater had broken shortly after the start, leaving Constant and the rest of the crew wet and bitterly cold.

The racers slept downstairs in shifts on pipe berths hung from the hull side. Pillows were banned to save weight. As the boat slammed from wave to wave, the crew took ten-minute meals of freeze-dried gruel squatting on their haunches. Eating was "like trying to eat a bowl of beans on a roller coaster," said Clougher.

Steve Erickson, in charge of clothing, fitted every crew member with three layers of heat-trapping fleece, polypropylene, and Gore-Tex, but everyone complained of cold, even inside the cabin. "I'm wearing everything I brought, including snow hat and gloves," Rudiger tapped out on his laptop computer. "My feet are freezing."

By the time the boat passed the Kerguélen Islands, the crew had learned to adapt. When a green roller roared down the deck "you just lie down and grab something solid with both hands," said Erickson. "Then it's like diving through a wave at the beach. You duck and go under, only the water is three degrees [Celsius], the boat is doing the diving, and you just hang on, hold your breath, and wonder when you're going to come out the other side."

Those who didn't take such precautions ended up regretting it. Clougher was picked up by a wall of water that sent him careering down the deck backside first into the starboard steering wheel, bending it like a pretzel. Mark Christensen let a roller thump him in the back, which sent him face first into a set of stainless steel shrouds, knocking one front tooth out and chipping the other. "I thought about spitting it out," he said. "But I heard if you jam them back in, sometimes they reattach." He forced the tooth back and it stuck.

All the while, Cayard pressed through black nights and gray, stormy days, hoping to overtake *Toshiba* ahead and to hold off the hard-charging British entry *Silk Cut*. Then came real trouble.

It was dawn on the 14th day, the wind howling 30 knots as usual, big seas rolling up

**HEAVING BOW** of the *EF Language* soaks crewmen Curtis Blewett and Steve Erickson as they work to set a spinnaker. Belowdecks (left) Marco Constant repairs sails with a sewing machine. Behind him a weary crewman rests in a pipe berth. The crew works and sleeps in four-hour shifts, never bathing and eating nothing but the freeze-dried equivalent of gruel.

from astern with squalls all around. *Silk Cut* was gaining ground, and *EF Language*'s crew was trying to set a spinnaker. Bowman Curtis Blewett was up the mast, dangling from a rope 85 feet in the air while the boat shouldered aside the towering seas.

"Looking down, I could see everybody in the red glow from the instruments," said the young Canadian. "They were tense, waiting for something to happen. I knew it was dangerous up there, but I thought, this is too cool; I'm going to wait and see what happens."

Blewett, 25, had gone aloft to secure the head of the spinnaker when it was deployed. The wind rose as he went up and was now too strong for the sail, which was still wrapped in a nylon sheath. The crew waited for a lull to open it, but a gust popped the sheath and the sail snapped full.

Helmsman Olsson was instantly overpowered. The low-slung boat spun out, the rudder lost its bite, the bow sheared into the wind, and the force of the wind slammed the yacht on its side in a vicious broach. Cold seas swept over the hull. Blewett, a recreational rock climber and the nephew of a grizzly bear hunting guide, clung to the shuddering mast with a bearlike hug, thinking, "If you let go now, you're done."

The boat shook and bolted upright, sails flailing. Blewett watched the carbon-fiber pole that the spinnaker is set from snap below him and the boom vang, a six-foot-long metal strut that holds the boom down, explode in two. He wondered if the mast would break.

"It was terrible," said Cayard, who was watching from the cockpit. "The mast was shaking, the spinnaker was tearing itself to shreds, and Curtis was stuck in the middle."

"I could see his leg flopping around," said Rudiger. "I thought for sure it was broken."

Someone shouted to cut the halyard that held the spinnaker up but in the confusion the halyard man slashed the wrong line—the one holding Blewett up. Cayard looked aloft, expecting to see his bowman free-falling to the deck or into the frigid sea. "I thought he was going to die."

By uncommon sailor's luck Blewett had clipped a spare line to his climbing harness, a damaged halyard he'd planned to bring down for repair. He dropped a few feet and fetched up on the backup line. "I've got him on this one," shouted Rudiger.

Rudiger lowered him to the deck. Crewmates helped him below and put him in a bunk next to Josh Belsky, who'd been knocked unconscious when the spinnaker pole broke

**FRIGID BLASTS** are borne by crewmen who must continually grind winches to trim sails. Body harnesses are clipped to jack lines for safety. So fast is the boat—sometimes reaching 35 knots—that it can surf down the flank of one wave and stab its bow into the next. Without superior helmsmanship, the boat could then spin out in a perilous broach.


SONY
SONY

**CROW'S-EYE VIEW** reveals a no-nonsense design (left). Though *EF Language* came in fifth in the second leg, the exhausted crew's spirits rose as they approached Fremantle (below). For a boat, salaries, and expenses, each sponsor invests about ten million dollars. The winner gets no cash prize, just a handshake, a trophy, and glory.


over his head. When they came to, each asked the other, "What are you doing here?"

Exhausted, with no gear left for battle, Cayard did the unthinkable and surrendered, at least briefly. As rival skipper Lawrie Smith on *Silk Cut* roared by to claim fourth place with a record run of 449.1 miles in 24 hours—the most ever by a monohull sailboat in one day—Cayard took a break to lick his wounds.

"What we have to do now is take time out," he wrote from the cramped, frigid navigation station. "Two hours of nothing. Two people on deck just making minimum headway. When the [spinnaker] pole is fixed and we have some rest, we'll start racing again."

Three days later *EF Language* is charging up the Indian Ocean, crewmen monitoring the water temperature with satisfaction as it increases a heartwarming 10°F a day. We intercept them off Cape Naturaliste in a gray dawn that soon gives way to patchy sunshine.

Cayard is dozing when I get aboard but pops up the companionway, wiping sleep from his eyes. He has a fresh scar on his cheek, a nasty tear he'd opened when he bashed his head into a bulkhead below as he tried, of all mundane things, to have a pee."Nothing is easy in the Southern Ocean," he says.

Later that afternoon Rottnest Island heaves up on the horizon, with sandy beaches and people at play and the skyscrapers of Perth looming an hour beyond. Power boats greet us, horns blaring, wives and kids and photographers waving. And now the cannon's boom, signaling the finish, and cheers from shore. It's over, 16 days, 20 hours—nearly two days after first-place *Swedish Match*, but even a fifth-place finish doesn't look so bad.

Cayard is philosophical about his mistakes, comparing his handling of the finely tuned boat to that of an Indy car. "In this race, sometimes you have to downshift, put it in third gear, and take a break," he says. "That's something I had to learn, and I did, the hard way."

By next morning all the bad memories will already be fading. The lads from *EF Language* will swap yarns with rival crews and feel the first yearnings to get back to sea, and to the Southern Ocean in particular.

"It's the worst place you've ever been," one Whitbread veteran says. "And the best place you've ever been." □

*Share the thrills of the Whitbread race on our online forum at www.nationalgeographic.com.*


GEORGE L. RISEN

■ FROM THE GEOGRAPHIC ARCHIVES

## Foul Wind of a Climate Change

Roiling toward Hooker, Oklahoma—in the heart of the Dust Bowl—a dust storm was captured from a local rooftop on June 4, 1937. Drought compounded by poor agricultural practices caused severe erosion across the Great Plains states in the 1930s. Without native grasses or moisture to hold the soil down, untold tons of dirt rose in the prairie winds, often darkening skies for days at a time and scouring the land in 50-mile-an-hour gusts. In the aftermath houses lay half buried in blown dirt, livestock died, and cars were stripped of paint. The federal Soil Conservation Service, created in 1935, introduced techniques like terracing, contour plowing, and crop rotation, but thousands of Okies continued to flee the dust and poverty for a new start in California.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NATIONAL GEOGRAPHIC

# *On* Television

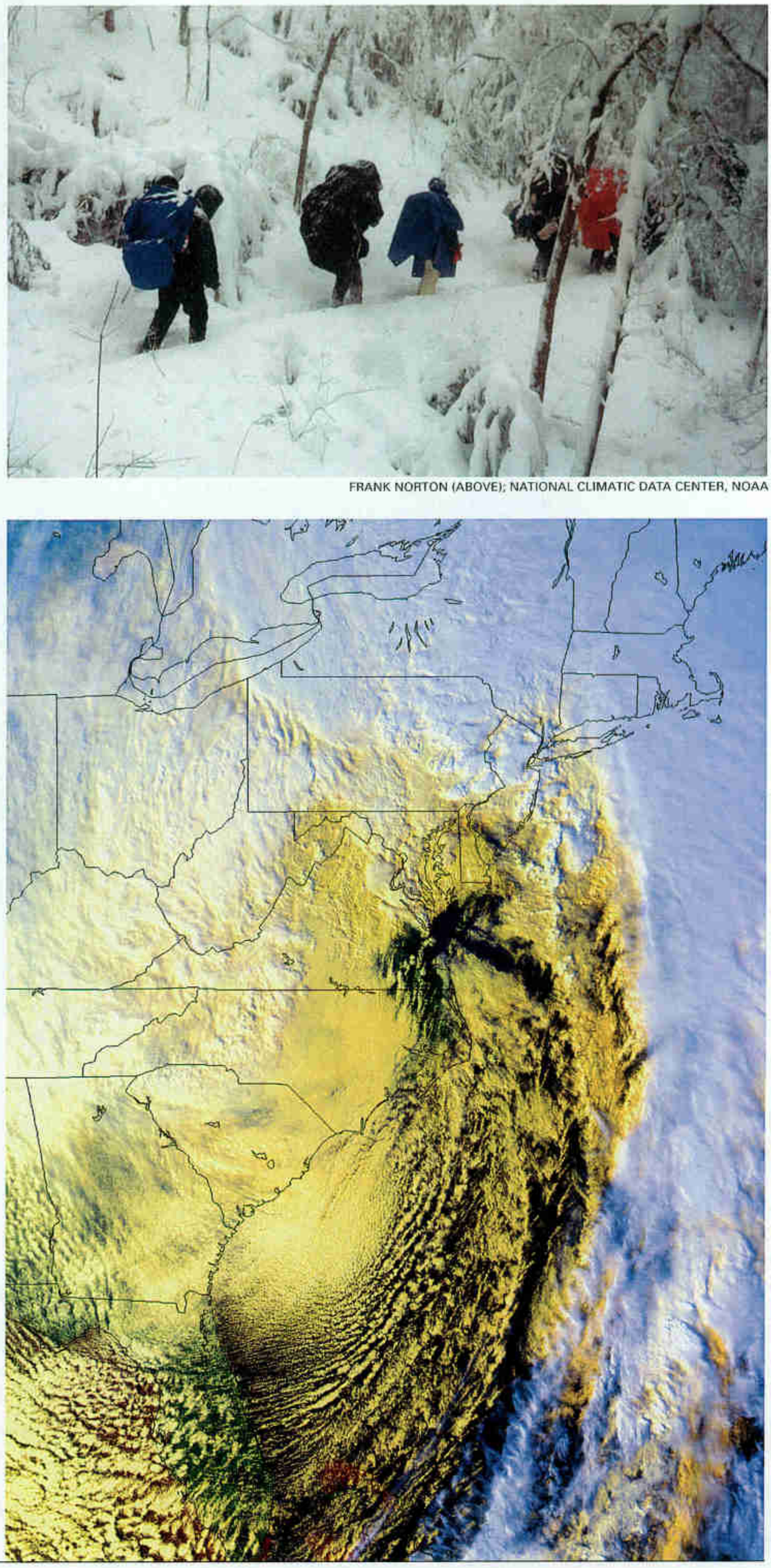
BYRON E. SMALL, *KNOXVILLE NEWS-SENTINEL*

■ SPECIAL, MAY, NBC

## Superstorm Coming!

One of the worst winter storms ever to hit the United States punctuates the sky over the Atlantic seaboard in a color-enhanced satellite image (lower right). Born in the Gulf of Mexico, the superstorm of March 1993 raked the East Coast, delivering deadly sea surges, tornadoes, and blizzard conditions as far south as Georgia. In some places the record-breaking low pressure system generated winds topping a hundred miles an hour. The new National Geographic Special "Storm of the Century" tracks the monstrous storm and the havoc it wreaked.

Among those who felt the storm's wrath was a group of students (upper right) trapped while camping in Great Smoky Mountains National Park. They endured subzero cold, waist-high snow, and screaming winds until they and their faculty leaders were rescued (top).



FRANK NORTON (ABOVE); NATIONAL CLIMATIC DATA CENTER, NOAA

■ PROGRAM GUIDE

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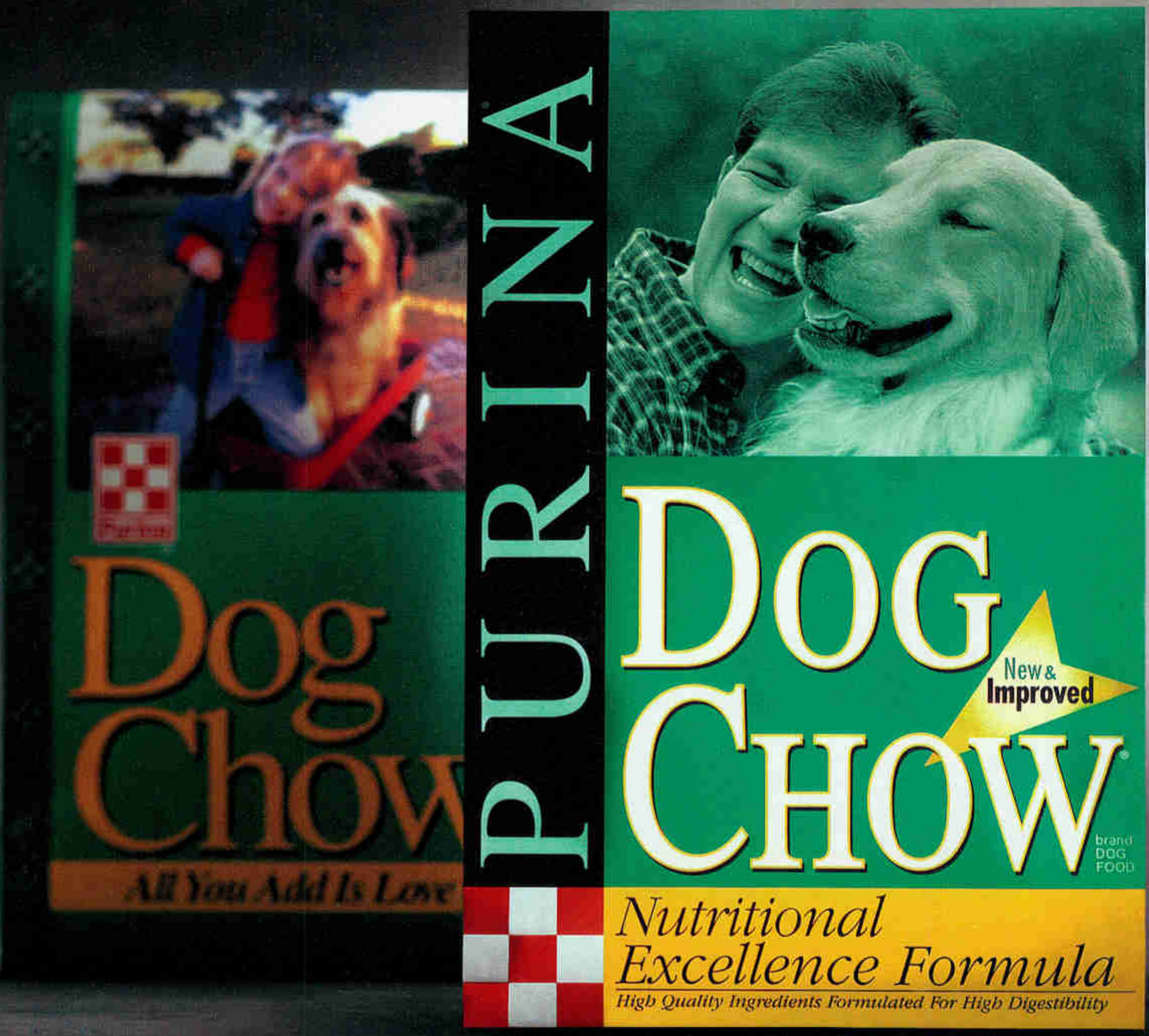


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NATIONAL GEOGRAPHIC

# *Earth* Almanac

MITCH KEZAR

## Paddles or Propellers?

Quiet may soon be harder to come by in Minnesota's million-acre Boundary Waters Canoe Area Wilderness. Two bills before Congress would allow an increase in motorboat use on some of the area's 1,100 lakes. Three portage trails closed to motor vehicles by court order in 1992 would be reopened to trucks hauling motorboats between lakes. The majority of the 200,000 annual visitors paddle canoes in this most heavily used of federal wildernesses. Fishermen, many in the nearby town of Ely, complain that motor restrictions deny them good fishing spots.

"This issue goes back a good 70 years," says Kevin Proescholdt, who heads Friends of the Boundary Waters Wilderness. "Sometimes you can hear an outboard motor six or seven miles over the water."

## Can Old Tires Smell Good?

What to do with the 260 million tires thrown away in the U.S. every year? Some are burned to generate electricity, but an experiment by University of Northern Iowa chemist Kirk Manfredi is more creative. He cooks shredded tires at 725°F in an airless furnace and, after distilling the gooey result, eventually winds up with limonene, a major component in the oil of lemons and other citrus. The extract could be used in flavorings and soaps, if commercial production ever becomes feasible.

BERT L. FOX, NGS

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## Deadly Algae Attack Leaves Rare Monk Seals Rarer Than Ever

Until last May only about 700 Mediterranean monk seals were thought to exist, swimming in European and African waters. Then the news got worse. The largest colony, on Cap Blanc in West Africa, lost 211 out of a total of 317 seals, including this one. Many scientists believe the victims died after eating fish contaminated by dinoflagellates, or toxic algae, although in a few corpses a virus was also detected.

"The number of survivors is still large enough for a recovery," says Alex Aguilar, a University of Barcelona biologist. "But any event like this in the near future may bring the colony to extinction."

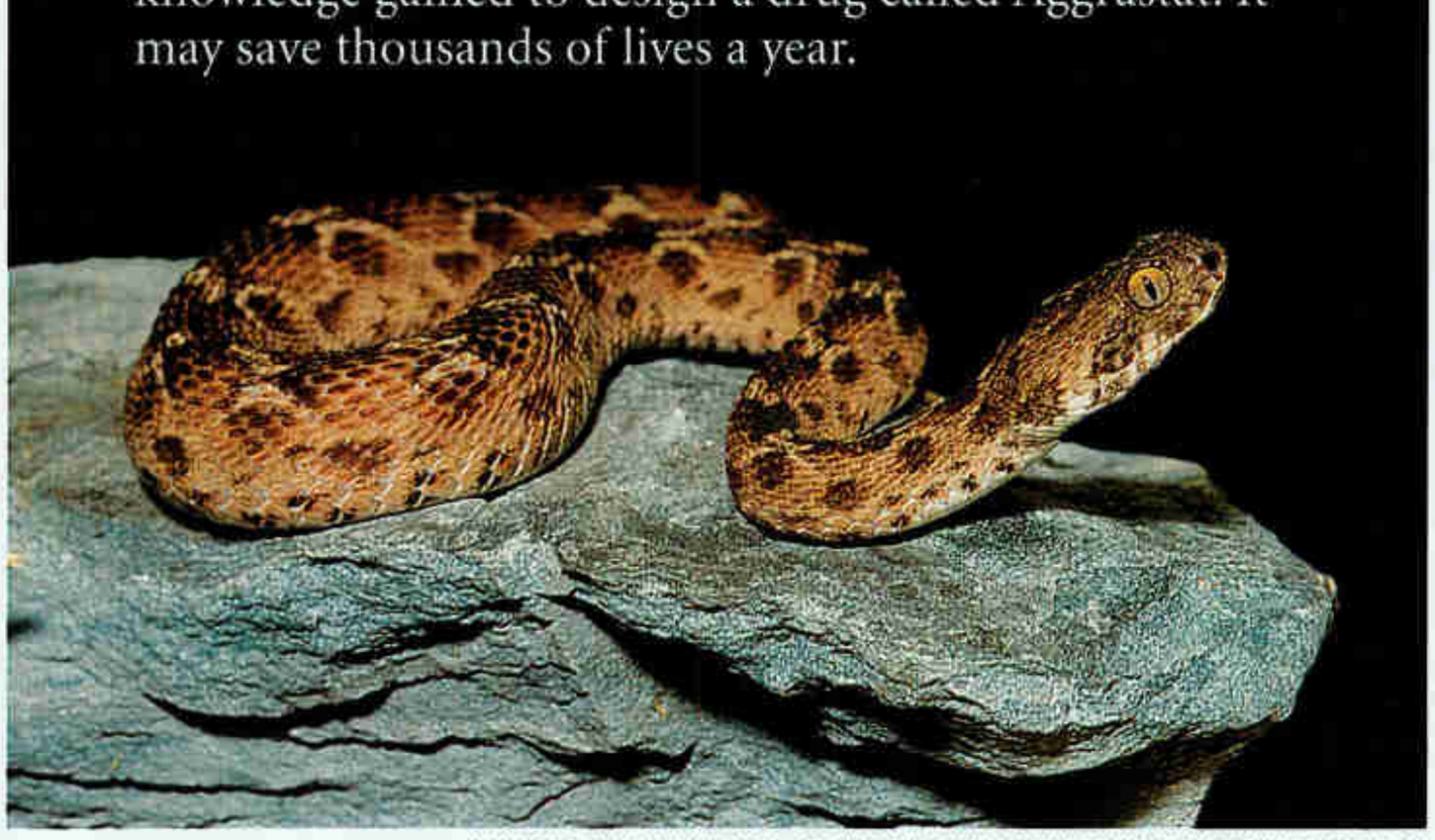
Historically, the seals were harvested for their oil and fur. Modern-day pollution, habitat destruction, conflicts with fishermen, and boat traffic have also taken a toll.

Perhaps named for a smooth, round head that resembles a monk's hood, monk seals also include a Hawaiian species. The Caribbean monk seal, almost certainly hunted to extinction, has not been seen since 1952.

ALEX AGUILAR, UNIVERSITY OF BARCELONA

## Snake Venom Strikes at Heart Attacks

Animals bitten by some snakes bleed internally, because the venom contains an anticoagulant. For the past decade researchers have studied snake venom in search of a drug that would prevent blood clots that can trigger heart attacks. Robert Gould of Merck Research Laboratories thinks his company has found one: "We tested 11 kinds of vipers and found proteins in their venom that keep human blood platelets from sticking together." Merck synthesized one of the proteins of a saw-scaled viper's venom and used the knowledge gained to design a drug called Aggrastat. It may save thousands of lives a year.



JOHN MITCHELL, NATIONAL AUDUBON SOCIETY COLLECTION/PHOTO RESEARCHERS

A-Z BOTANICAL COLLECTION

## Treating Toxic PCBs With Toxic Plants

Named for Atropos, a Greek goddess who determined the length of one's life, deadly nightshade *(Atropa belladonna)* is a poisonous plant from Europe, Asia, and northern Africa. Now Czech researchers have found a new role for nightshade: In their lab it absorbs and detoxifies PCBs, major pollutants. Martina Macková and her colleagues at the Institute of Chemical Technology in Prague are beginning tests in contaminated soil, planting nightshade infected with a bacterial parasite that whets the plants' appetite.

TEXT BY JOHN L. ELIOT

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NATIONAL GEOGRAPHIC

# *Inter*active


■ ONLINE

## Hot Topics and a Cool Kitty

A compendium of challenging ideas rewards a visit to our millennium website. Essays, features, and forums stimulate consideration of wide-ranging topics—from medieval China to modern Manhattan, from the ocean floor to the poisoned skies. Join us at *www.nationalgeographic.com/features/2000.*

■ To science editor Rick Gore a walk across hot coals seemed like a perfect metaphor for Cascadia, a region threatened by earthquakes and volcanoes. So he doffed his shoes and faced the fire. Feel the heat at . . *./features/2000/physical/firewalk.*

■ Jane Goodall has seen environmental tragedies, yet the chimpanzee expert has hope. In the first in a series of "Famous Faces," she talks with us about the millennium at . . *./features/98/faces/goodall.*

■ Greg Marshall wanted to know what his cats did all day while he was away. The scientist-filmmaker adapted his crittercam—which has filmed the sea from the backs of sharks and whales—for its terra firma debut. Chart the history of the crittercam at . . *./features/98/crittercam.*

■ Wolves in Yellowstone—environmental triumph or lunacy? Read "Return of the Gray Wolf" and join our forum at . . *./media/ngm/9805/forum.*

■ FOR INFORMATION

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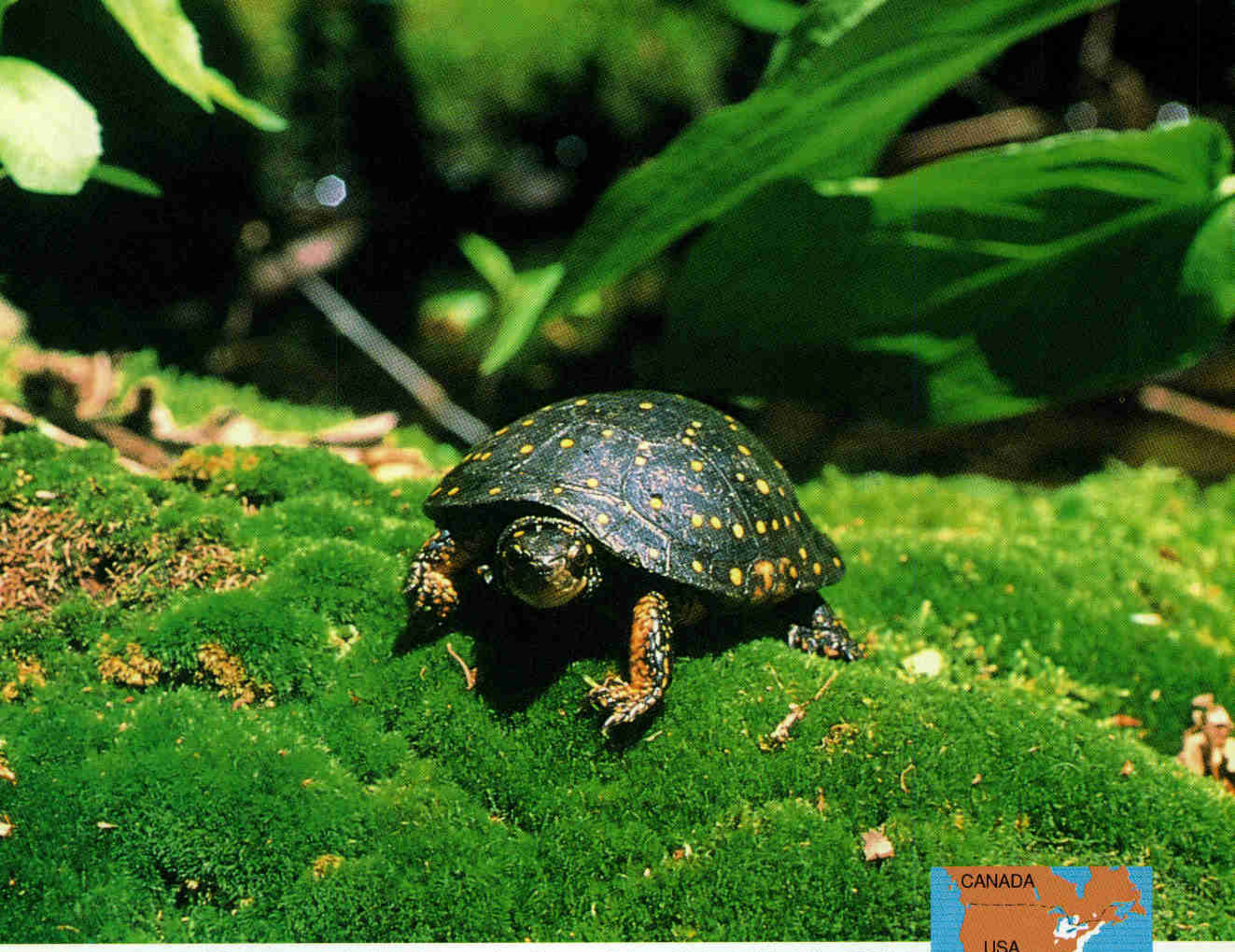
TIMOTHY C. GREENLEAF, NGI




**Spotted Turtle** *(Clemmys guttata )* **Size:** Carapace length, up to 13.1 cm **Weight:** 125 - 350 g **Habitat:** Quiet streams and marshlands in the midwest and eastern USA, and southern Ontario and Quebec, Canada
**Surviving number:** Unknown
Photographed by John L. Behler

# WILDLIFE AS CANON SEES IT

On a cold spring day a spotted turtle crawls out of its nocturnal retreat to bask on a mossy bank. Restored by the sun's heat, it returns to the water to prowl the leaf litter and emerging plants for aquatic insects, crustaceans, and frog and salamander eggs. Now and again, the little turtle's bright yellow spots, which turn dull and muted when the carapace is dry, appear near the water's surface as it rises to breathe. Spotted turtles have evolved to contend with seasonal changes, but are declining from habitat alteration and fragmentation, and pet trade collection. As a global corporation committed to social and environmental concerns, we join in worldwide efforts to promote greater awareness of endangered species for the benefit of future generations.

NATIONAL GEOGRAPHIC

# *On* Assignment

JOANNA B. PINNEO

■ THE CLIMATE PUZZLE

## Weathering the Road

"I tried to stay ahead of the rainy season," explains photographer Joanna Pinneo of her eight-country shooting schedule for this story. Rain wasn't a problem in Mali though. Joanna drove for days across the desert "on nothing that ever looked like a road" to photograph the Mohameds, a family of nomadic Tuareg. "Since my translator was a man, he felt uncomfortable in the women's tent, so I usually didn't understand a thing they were saying," says Joanna. "But they were so accepting of me, I felt we'd had long, wonderful conversations."

BOB SYMONDS

■ CASCADIA

## On the Hot Seat

"The hardest part of shooting the Cascades," says photographer Jim Richardson, "is seeing them in the first place." During much of his visit the mountains hid behind clouds. Other problems: On Mount Baker (left) Jim did without goggles that would protect his eyes from acrid fumes. "My glasses wouldn't fit under them, and I need my glasses to see. One thing I could see, though, was my camera lens fogging up from the steam!" Jim gained a valuable lesson from his time inside Cascadia's gassiest volcano. "Never sit on a steaming fumarole. Jeans will not protect you."

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NATIONAL GEOGRAPHIC

# Geoguide

**Tranquilized wolves from Canada are muzzled during transfer from pen to pen in Yellowstone National Park. Muzzles help protect eyes and calm nerves. No coaxing is needed to lure a wolf into a large holding pen prior to its release into the park (right). In Salt Lake City a tamed wolf travels with a Colorado-based program that discourages the breeding of wolf hybrids as pets.**

JOEL SARTORE (BELOW); RICK RICKMAN

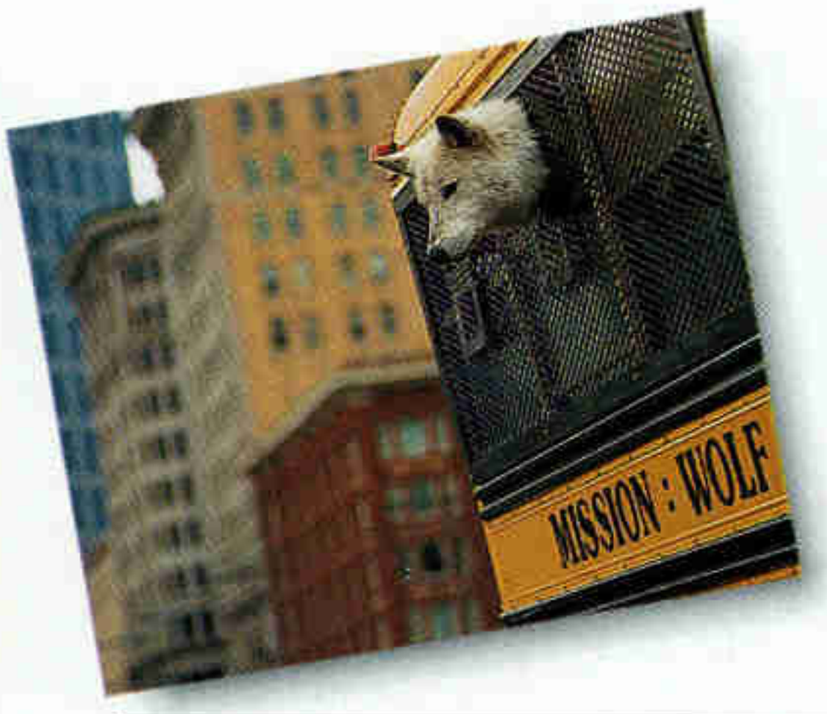
## The Gray Wolf Returns

■ The map on page 81 shows a drastic reduction in the distribution of gray wolves in North America from the past to the present. What relationship can you see between the current range of wolves and today's range of human settlement?

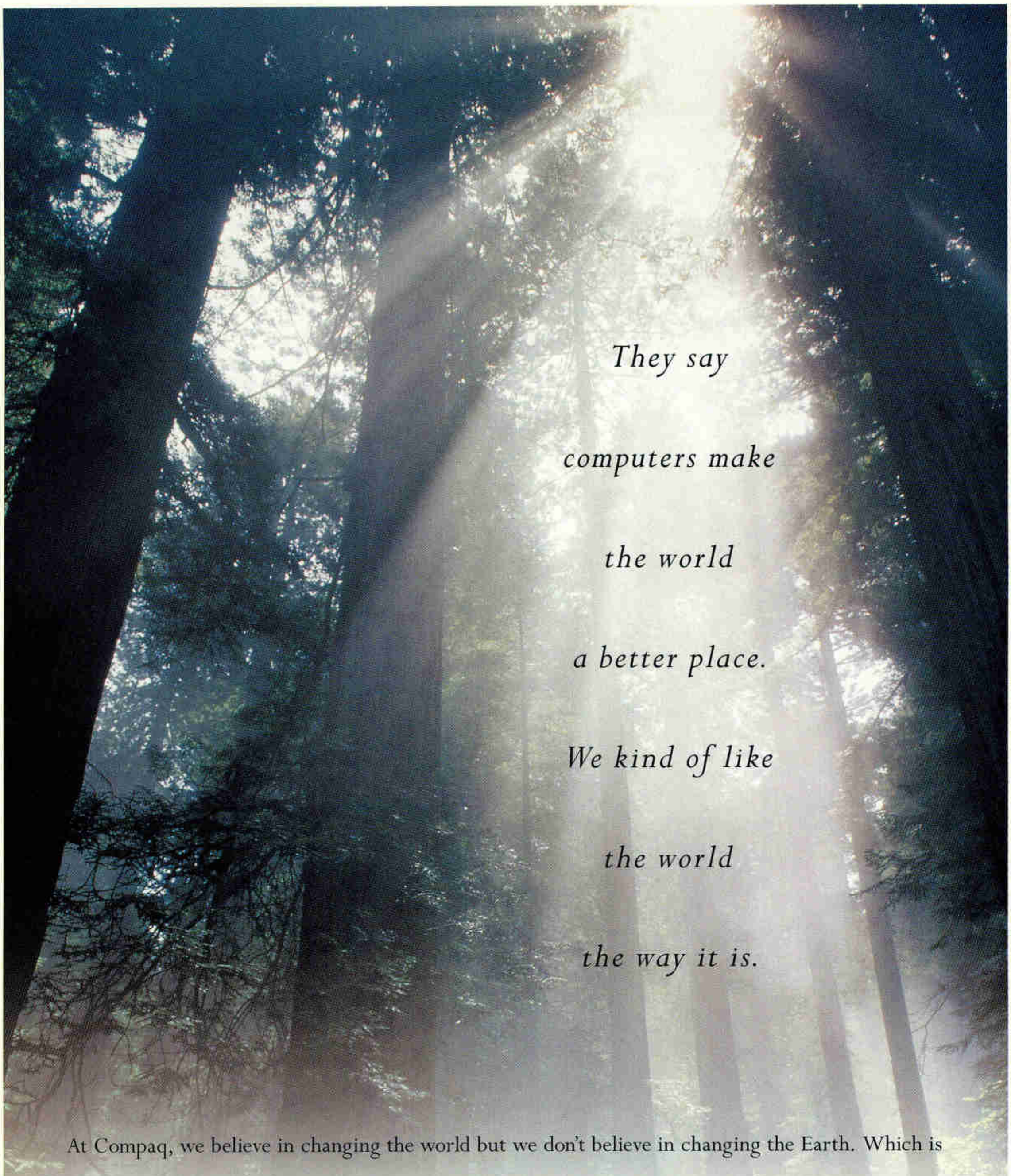
■ The grizzly bear and the cougar, also called mountain lion or panther, once lived in much of North America, just as the wolf did. Like the wolf, these animals were nearly exterminated in most areas of the lower 48 states. Yet other large wild animals, such as white-tailed deer and mule deer, thrive today in their original range, and in many places are even more numerous now than they were a hundred years ago. Can you suggest why we have protected some wild animal species but allowed—or encouraged—the elimination of others?

■ In "Little Red Riding Hood" and many other stories the wolf is portrayed as a crafty creature dangerous to people. The record shows, however, that healthy wolves do not hurt people, except in self-defense. In fact, they are so wary and secretive that they're often difficult to spot in the wild. Why did the wolf earn such a bad reputation in the past? Why does the wolf still have a bad reputation with many ranchers who raise cattle or sheep for a living—and with some sport hunters? Why, then, is the wolf's popularity now rapidly increasing among many other people?

■ On page 91 author Douglas Chadwick describes how wildlife agents used immobilizing drugs to capture a female wolf called B11, then put her in a helicopter and flew 160 miles before releasing her. Yet in only 11 days she traveled all the way back to her mate. On average, how many miles did the wolf have to travel each day? To get an idea of how much country B11 crossed in that short time, examine your own region using a road map or atlas. What towns or landmarks lie 160 miles away from your hometown? How long might it take you to walk that far?




USE GEOGUIDE ALONG WITH THE ARTICLE ON GRAY WOLVES IN THIS ISSUE TO CAPTURE THE INTEREST OF YOUNG READERS AND STIMULATE DISCUSSION. YOU CAN VISIT GEOGUIDE ONLINE AT WWW.NATIONALGEOGRAPHIC.COM/RESOURCES/EDUCATION/GEOGUIDE.

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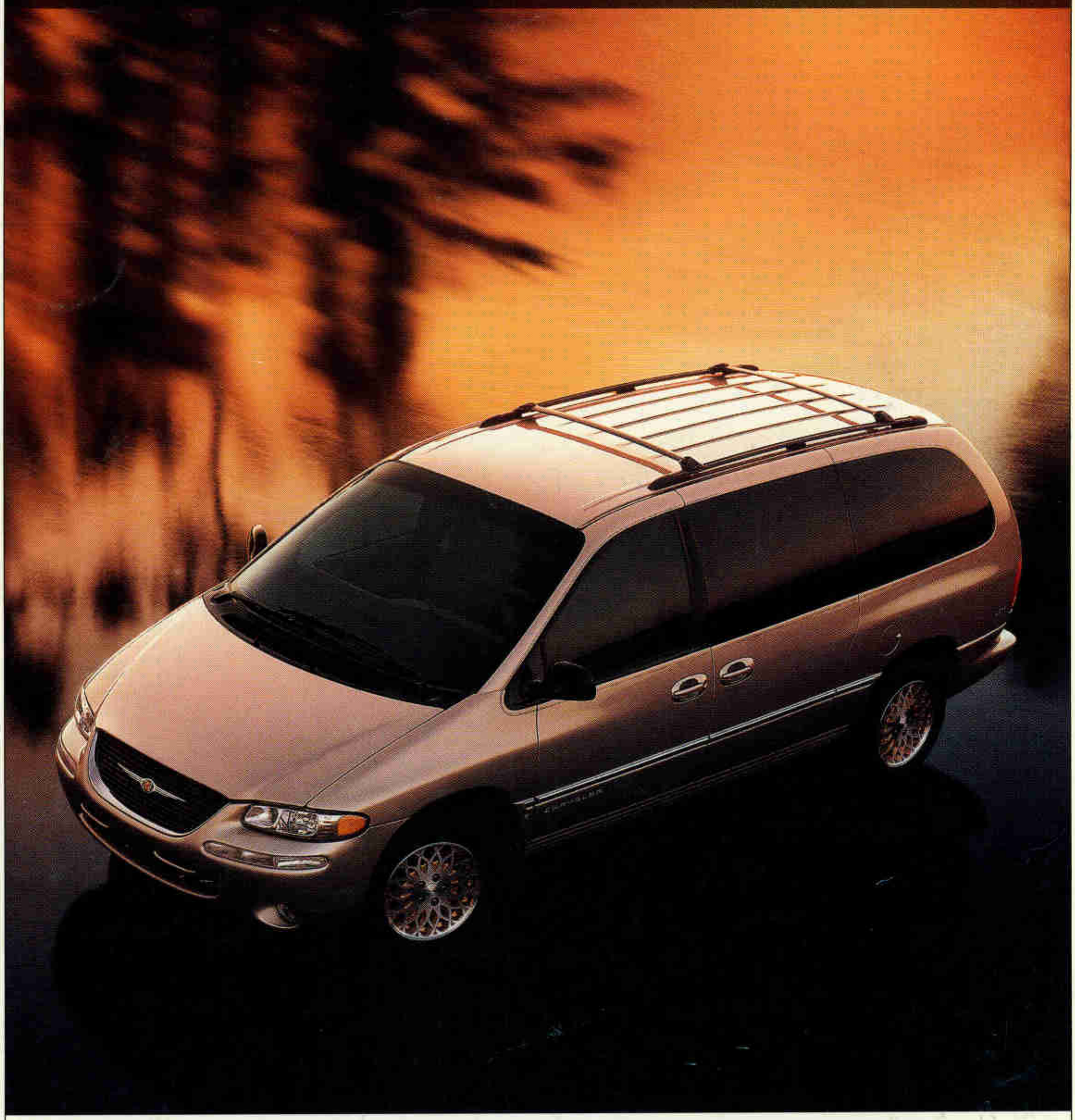
The New Chrysler Town & Country

# We made it exceptionally quiet. However, it still produces an occasional buzz.

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